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ORIGINAL ARTICLES.

Notes on Brimstone Hill, St. Kitts.

By C. T. Trechmann, D.Sc., F.G.S.

Petrology by T. S. Westoll.

(PLATES XIV and XV.)

BRIMSTONE HILL, 779 feet high, on the north-west side of the island of St. Kitts, or St. Christopher, about a third of a mile from the sea, lies about 2½ miles south-west of Mount Misery, the culminating point, which is said to be 3,711 feet high and to have a crater lake. Several other peaks of the island rise to over 1,000 feet, and to the south-east of Mount Misery another weathered cone is Mount Olivees, 2,781 feet high. About 12 miles to the north-west of St. Kitts is the Dutch island of St. Eustatius, or Statia, a dormant volcanic cone about 594 metres high on the south-west side of which great slabs of white sedimentary rock, called the White Wall, are seen tilted up against the side to a height of 315 metres. Further still to the north-west is the volcanic cone of Saba. South-east of St. Kitts, and nearly adjoining it is Nevis, which consists of a central cone and several subsidiary craters. These islands—Saba, St. Eustatius, St. Kitts, and Nevis—lie in a slightly curved line in a north-west and south-east direction.

I recently spent a week on St. Kitts and paid several visits to Brimstone Hill, and examined it in some detail, so the following observations may be of some interest to geologists, as I find the previous accounts conflict in several points with my own observations. Brimstone Hill is the old "Gibraltar" of the West Indies, and is crowned by the most extensive and elaborate of the old fortifications of these islands.

Brimstone Hill is obviously a plug extruded comparatively recently, and has carried up on its sticky flanks and shoulders the curious upturned sedimentary beds which occur around it on all sides except the north-easterly, and which on the east side rise nearly to the level of the summit. The plug has not merely raised, but has broken through the various layers of sedimentary rocks, so that there has been considerable complication and smashing up of the beds. The sedimentaries are thickest and most massive on the lower slopes of the west and north-west side of Brimstone Hill, where they make up a great part of the lower mass of the hill.

In shape and petrological composition the igneous core of Brimstone Hill bears comparison with the spike or spikes, some 900 feet high, which were extruded from the summit of Mount Pelée, Martinique, during the destructive eruption of 1902.

Another marine limestone, but very poor in fossils, is reported to occur at Godwin Gut, St. Kitts, at a height of 1,150 feet. Unfortunately I did not know of its occurrence, but it appears to be of the age of the Antigua limestone, and therefore much older than the sedimentaries of Brimstone Hill.

DESCRIPTION OF BRIMSTONE HILL.

The small light-coloured patch seen near the base on the right-hand side of the photograph (Pl. XIV, Fig. 1) on the south-east flank consists of yellow and pink chalky limestone, generally soft, but hard in places, and has a few fossils, Pectens, and foraminifera. The bedding is obscured, but the dip is apparently away from the hill.

On the east-north-east flank, just round the hill on the right, facing Mount Misery, the limestone rises steeply to about 650 feet, and occurs as irregular dense broken masses, evidently hardened by the intrusion, and very weathered and precipitous. The bedding is obscured, and fossils are found only rarely and as broken casts. I found the cast of the apical part of a *Ficula* (?) near the summit, only a foot or two away from the junction with the igneous rock.

The north-east side of Brimstone Hill is occupied by the vertical or overhanging cliffs of the volcanic extrusion, which rise up to 750 feet, the sedimentaries being absent there. The highest point of the hill is formed of the igneous rock, which shows numerous joint planes running in various directions, but chiefly more or less vertically.

At a spot called Magazine Bastion, about 520 feet high on the north-west side, I observed about 20 feet of grey, ashy, and agglomeratic chalk, not far from the junction with the volcanic rock, enclosing masses of grey porous marly limestone, made up of small shell fragments and foraminifera, each grain having a grey incrustation around it. It has a few branches of a coral-like growth running through it, and I found in it badly preserved fossils, including *Trivia* sp., *Chama* (?), and a valve of *Lucina* (*Phacoides*) *aurantia*, and other small indeterminable gasteropods. It may be a bed altered by volcanic emanations. This seems to be the highest point attained by the sedimentaries on the seaward side of the hill. Further away on the edge of the west-north-west slope, about the same height, the limestone becomes whiter and less agglomeratic.

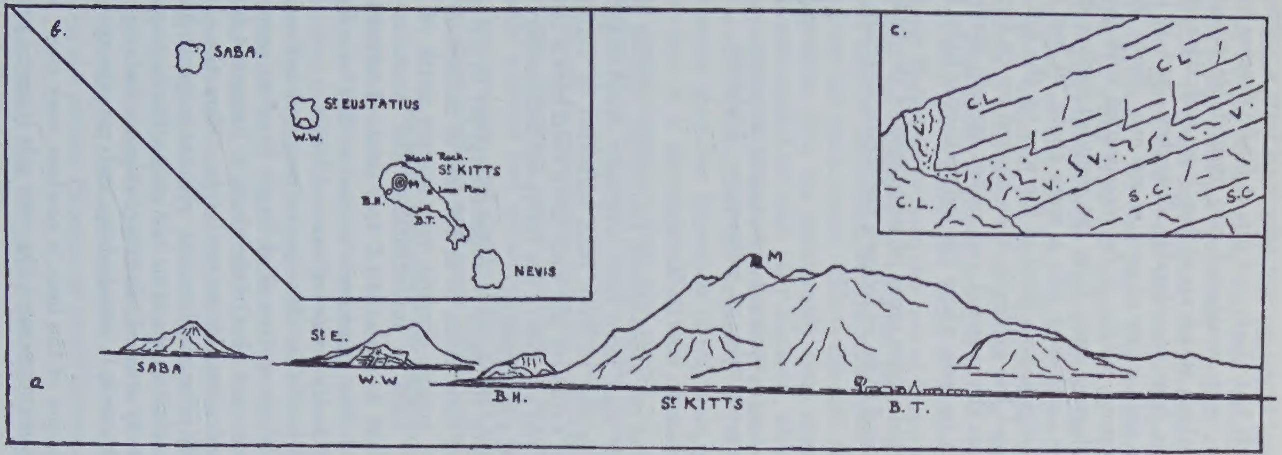

Fig. 1.—*a*. A view sketched from the sea off Nevis showing the western part of St. Kitts with Brimstone Hill (B.H.) at the foot of Mount Misery (M.), columnar structure near the top. B.T. is the town of Basse Terre and secondary craters on the sides are indicated. St. Eustatius (St. E.) with the upturned sedimentaries called the White Wall (W.W.) resting against the side of the cone. Further away is the volcanic cone of Saba. *b*. Sketch-map of the islands from Saba to Nevis. Lettering as above. *c*. Section of part of the raised sedimentaries on the west side of Brimstone Hill. C.L. Chalky limestone, S.C. shelly chalk, VV grey and red volcanic ashes to show how the latter are interbedded and twisted in among faulted and displaced shelly limestone. Height of the section about 30 feet.

On the west side coral limestone and ashy marl form a series that may be as much as 200 feet thick, and dip at 60–65 degrees to the north-west, and have been weathered into formidable pinnacles, 100 feet or so high, which stand up at the base and sides of the hill. The limestone is here considerably disturbed, and is interbedded and faulted in with layers of grey or red ash. Slabs 30 feet thick of coralline limestone overlie or are interbedded with pockets of ash and dip at 60 degrees away from the rounded surface of the igneous rock. On the south-west side a mass about 26 feet thick of white ashy limestone rises to a third of the way up the hill, dips at about 75 degrees, and has evidently been hoisted up on the side of the volcanic plug, as the rounded and rather smooth surface of the andesitic lava can be seen where the sedimentaries have fallen away.

On the north-west side some order of succession of the beds can be made out, and seemed to be as follows, the strata standing more or less vertically :—

	Approx. thickness in feet.
Light brown, ashy, limestone or chalk full of Pectens of the *zic-zac* type (*P.* cf. *bowdenensis*), *Ostrea* cf. *paramegodon*, *Diplodonta rotundata*, etc.	20
Chalky limestone and marl	2
Grey unfossiliferous volcanic ash, next the intrusion . . .	15

Some of the grey and red ashes among the steeply dipping chalky beds on the west side may have been originally interbedded, but in some cases they appear to have been sprinkled in during the uplift. A quantity of explosive ash may have been blown out and have filled up cracks and cavities in the fractured sedimentary mass as it was being raised and extruded.

On the south-east side the massive andesites appear to dip nearly vertically, and against these come 80 or 100 feet of calcareous tuffs, with broken massive corals, dipping very steeply north of west. A fossiliferous grey marl is interstratified and contains well-preserved fossils. Next comes a bed 3 feet thick of twisted grey marly ash and, outside that, massive white calcareous beds dipping nearly vertically with badly preserved casts of fossils.

The best preserved fossils are those in the grey and buff-coloured agglomeratic chalks where specimens of fragile bivalves occur with both valves in position, and also in the chalk or limestone furthest away from the intrusion on the seaward side. Here the chalk is often full of beautifully preserved bivalves, with the valves in position or slightly displaced, while in the same bed only a few feet away the fossils may be completely crushed. In other limestone beds especially near the intrusion the rock is smashed up and massive corals are shattered.

The order of succession of the beds is nowhere very clear, but as they dip away from the intrusion on the west side it seems probable that those next the intrusion, the grey agglomeratic chalks with Pectens of the *zic-zac* type, and the volcanic ashes are the oldest and the white coralline limestones furthest away from the intrusion the latest. It is not improbable that inversion may have taken place, as at the north-west corner the whole mass of sedimentaries stands about vertically. At this point the sedimentaries seem to extend 250–300 ft. away from the igneous mass, but it is rather uncertain whether this represents the original thickness of the beds, as repetition by faulting or crushing may have taken place. Solfataric action may have occurred, as, near the junction with the intrusion, the sedimentary beds seem to be altered; on the west side of the hill at the present day a strong smell of SO_2 or H_2S is noticed, which is said to have given rise to the name of Brimstone Hill.

About 30 feet away from the foot of Brimstone Hill, on the north-west side, an exposure of volcanic rock, of a type general over a great part of the island, occurs, and seems to have come at some time from the main crater. This is the rock through which the plug of Brimstone Hill has presumably been extruded. Otherwise the hill is surrounded by loose ashy material, which may be products of former explosive action reassorted by water.

It would appear that the extrusion of Brimstone Hill is a much later event than the formation of the cone of Mount Misery, near whose foot it is situated. The view that the sedimentaries are a late beach formation does not appeal to me; they seem to be older even than the main volcano of the island, but probably newer than the old volcanic accumulations at the south end of St. Kitts. It is difficult to imagine the massive white chalks and limestones to have been deposited round the edges of a very active volcano, but volcanic activity had already commenced, as the calcareous tuffs near the intrusion, and also to a less extent the white chalks, contain broken chips of glassy and other volcanic fragments.

FORMER ACCOUNTS OF BRIMSTONE HILL.

P. T. Cleve writes[1]: "At the foot of Mount Misery there is in Brimstone Hill a white limestone rock of considerable size, surrounded in all directions by loose volcanic rock. I have not seen in it any trace of stratification. The rock has the appearance of chalk, and contains many fossil shells and corals, the greatest number in the form of casts. I have found about forty-three different mollusca, all of species still living in the Caribbean Sea, except a single specimen of a *Modiolaria*, closely related to a still living northern species. Among the fossil shells one of the most common is *Tellina gruneri* Phil., also occurring in the Miocene strata of Cuba and Puerto Rico, and still living in the Caribbean Sea, but very rare." He places the fossils in the newest Pliocene or post-Pliocene.

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[1] "Geol. of the N.E. W. Indian Islands," *Kongl. Svensk. Vetensk-Akad. Handl.*, Bd. 9, 10, 1871, 21.

Professor J. W. Spencer[1] speaks of Brimstone Hill as being composed of loose or semi-coherent tuffs; and of the sedimentary mantle occurring to a height of only 450 feet. Further on he speaks of the limestone as underlying the submerged coastal plains; and the mollusca collected by him were determined by Mr. Charles T. Simpson as *Venus cancellata* Linn., *V. paphia* Linn., *Cardium sublongatum* Sow., *Glycimeris pectinatus,* and *G. undatus* Lam., *Lutricola interstriata* Say, *Tellina interrupta* Wood, and *Pecten zic-zac* Linn., all living species.

Karl Sapper,[2] in a paper mainly petrological, regards the rock of Brimstone Hill as much older than the, according to Cleve and Spencer, Pleistocene limestone; and regards the latter as younger layers on the previously existing Brimstone Hill.

K. W. Earle[3] describes Brimstone Hill as a "secondary adventitious cone on the flanks of Mount Misery, evidence of volcanic forces that did not culminate in eruption". He also states that "tuffs form the whole core of Brimstone Hill itself", and that the tuff as seen in hand specimens "consists of a very fine-grained consolidated, hard, grey ash, looking almost like a Palaeozoic limestone". He also says the "mantle of white marl or limestone reaching at the present time to an altitude of 400 feet, but almost confined to the shore side of the hill", and that "no true dip is visible in this limestone"; and that it is "a regular beach deposit crowded with shells and all of recent species". His collection comprises twenty-one species of fossils, including six corals, seven lamellibranchs, seven gasteropods, and echinoid fragments.

My own observations conflict in several points with the foregoing descriptions:—

1. I found the solid igneous rock at all parts of the hill I examined to be a hard, dark grey, andesitic material of a trachytic feel. This does not include the ash which has been sprinkled in among the upturned sedimentaries.
2. The limestones go up to nearly 100 feet below the level of the summit on the landward side.
3. I regard the sedimentaries not as a mere coastal deposit, but rather as part of a series of beds that underlie or may have underlain the main cone of the island, probably of late Pliocene age.
4. Many of the fossils on close examination show material differences from the corresponding living forms of the West Indian Islands.
5. The extrusion of the igneous plug is later than the deposition of the sedimentaries through which it has broken its way; and stratification is very clearly shown in the sedimentary beds.

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[1] *Quart. Jour. Geol. Soc.*, lvii, 1901, 536.

[2] *Centralb. für Min. Geol. u. Pal.*, 1903, 1, 286.

[3] *Reports on the Geol. of St. Kitts and Nevis, etc.*, pub. by the Crown Agents for the Colonies, Feb., 1925, 13.

ST. EUSTATIUS AND GUADELOUPE.

P. T. Cleve (p. 19) quotes Maclure speaking of the lime deposit on the south-eastern slope of St. Eustatius. The whole of this marine deposition dips to the south-west at an angle of upwards of 45 degrees from the horizon, resting upon a bed of cinders, full of pumice and other volcanic rocks, and is immediately covered by a bed of madrepore sand and cinders mixed together, with blocks of volcanic rocks so disseminated that there can be no doubt of the volcanic origin of the substance above and below the madrepore rock, which may be from 500–600 yards thick. Further on, he writes that the fossiliferous deposit, the White Wall, as well as the regular stratification of the tufa in the land around the cone, seem to prove that the lower part of the volcano is formed of submarine eruptions, and that the island has been raised afterwards.

G. A. F. Molengraaff[1] gives the highest part of the White Wall as 315 metres, and the rim of the crater of St. Eustatius as 581 metres; and he says on the south side are the White Wall and the Sugar Loaf, a subsidiary uplift, and on the south-east side of the Sugar Loaf there are nine divisions of beds which dip at about 45 degrees. The divisions are as follows (so far as I can translate the Dutch) :—

9. A glassy augite-andesite tuff (nearest the igneous mass).
8. Lava fragments with pieces of pumice.
7. A conglomerate with shells and corals.
6. Limestone with very numerous shells and corals.
5. Contains corals.
4. A pumice layer 4 metres thick.
3. Tuff breccia with some shells and corals.
2. A limestone layer.
1. The last formed before the uprise is a coral limestone rich in shells.

Molengraaff gives a list of species of mollusca from Brimstone Hill, St. Kitts, and from the White Wall, St. Eustatius; forty occur at Brimstone Hill and forty-eight at White Wall; seventeen species are common to both. All are apparently listed as recent species; those from Brimstone Hill are from Cleve's collection.

I could only look at the White Wall through binoculars from the north end of St. Kitts, but from this and from photographs the sedimentaries at White Wall look much less smashed up and more gently tilted than they are at Brimstone Hill. Whether the mode of uplift has been similar in the two cases I cannot say.

Regarding the volcanic western half of the island of Guadeloupe, Cleve writes: "In Basse-terre some fossiliferous deposits have been found by Mr. Payen. One of these deposits occurs at a height of 40 metres, about 50 metres from the shore, and the other, which rests upon horizontal beds of volcanic rocks, reaches the height of 100 metres and is 200 metres from the sea. They seem to belong to the same geological time as Brimstone Hill in St. Kitts."

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[1] *De Geologie van het Eiland St. Eustatius*, Leiden, E. J. Brill, 1886.

PALAEONTOLOGY.

Among the fossils from Brimstone Hill, besides mollusca, there are corals, Hydrocorallinae, occasional echinoderms, and innumerable foraminifera. I collected two crab claws, which Mr. T. H. Withers has kindly identified as belonging to a form of *Pagurus*. A sea-urchin has been identified by Professor L. H. Hawkins as a form of *Echinolampas*. The mollusca are not easy to determine, many of them being neither entirely Recent nor definitely Tertiary. They approach in many cases those of the Bowden Beds (Vindobonian) of Jamaica, and we are evidently dealing with a fauna that shows affinities with the recent but also to a less extent with the Bowden. The mollusca of Brimstone Hill have a considerably older aspect than those of the Coral Rock of Barbados, which may apparently be referred to the early Pleistocene. My interpretation of the Brimstone Hill mollusca is as follows: of forty-four varieties of gasteropods and lamellibranchs thirty-eight occurred in the outer chalks away from the igneous rock (marked O) and are presumably the newer; six were found in the grey beds with more volcanic fragments nearer the igneous mass (labelled I); ten forms are specifically uncertain (labelled U); seven seem to be identical with living species (marked L); twenty are evidently near the living species (marked N); seven are apparently fossil species (marked F); while two species seem to show affinities with forms on the Pacific side (marked P).

I should put the fauna down as Pliocene, possibly late Pliocene. If these attributions are correct, the West Indian Neogene molluscan fauna changes less as one goes back in time than does that of northern localities.

GASTEROPODA.

Cypraea cf. *cinerea* Linn. U.O.
Trivia sp. U.I.
Cerithium litteratum Born. L.O.
,, *caudatum* Sow. L.O.
Strombus gigas Linn. variety. N.O.
Fasciolaria cf. *tulipa* Linn. U.O.
Ficus (?) sp. U.I.
Oliva cf. *reticularis trochala* Woodring. N.O.
Natica (*Polinices*) cf. *subclausa* Sow. F.O.
Bulla cf. *vendryesiana* Guppy. F.O.

LAMELLIBRANCHIATA.

Ostrea (*Lopha*) cf. *paramegodon* Woodring. F.P.I.
Glycimeris cf. *pennacea* Lam. N.O.
,, *pallium* Reeve. L.O.
,, *oculatus* Reeve. L.O.

Arca (*Scapharca*) cf. *deshayesi* Hanl., var. 1. N.O.
,, ,, ,, ,, var. 2. N.O.
,, ,, ,, ,, var. 3. N.O.
,, ,, cf. *secticostata* Reeve, var. N.O.
,, cf. *imbricata* Brug. U.O.
Pecten cf. *bowdenensis* Dall. F.I.
Chlamys (*Plagioctenium*) cf. *nucleus* Born. N.O.
,, (*Aequipecten*) cf. *plurinomis morantensis* Woodring. F.O.
Pecten cf. *excentricus* Gabb. F.O.
Cardium (*Fragum*) *medium* Linn. var. *christopheri* nov. N.O.
,, ,, cf. *burnsii* Dall. N.O.
,, (*Laevicardium*) *serratum* Linn. L.O.
Chione cancellata Linn. var. *christopheri* nov. N.P.O.
,, cf. *paphia* var. *christopheri* nov. N.O.
Cytherea sp. U.O.
Codakia cf. *imbricatula* C. B. Ad. N.O.
,, (*Jagonia*) cf. *vendryesi* Dall. F.I.
,, near *orbicularis* Linn. N.O.
Divaricella cf. *prevaricata* Guppy. N.O.
Phacoides (*Linga*) cf. *podagrinus* Dall. N.O.
Lucina (*Phacoides*) *jamaicensis* ? Spengl. U.O.
,, ,, *aurantia* Desh. L.O.
Diplodonta rotundata Montagu. L.I.
,, cf. *semiaspera* Phil. N.O.
Capsa (*Metis*) cf. *intastriata* Sow. N.O.
Tellina (*Arcopagia*) *fausta* Pult. U.O.
,, (*Tellinella*) *interrupta* Sol. N.O.
,, (*Semele*) near *proficua* Pult. U.O.
,, (*Angulus*) cf. *similis* Sow. N.O.
Gastrochaena cf. *cucullata* Desh. U.O.

Description of the Fossils.

Cypraea cf. *cinerea* Linn.

Casts of *Cypraea* in the chalky limestones may be this living West Indian species.

Trivia sp.

An indeterminable cast occurred in grey ashy beds near the igneous intrusion.

Cerithium litteratum Born. Pl. XV, Fig. 18.

A well-preserved specimen in the white chalks on the west side.

Cerithium caudatum Sow.

Three broken specimens with the above agree with recent specimens from the Gulf of Paria, Trinidad.

Strombus gigas Linn. var.

Specimens of this large shell occur in the chalks on the west side; but are generally broken up. I only collected the spiral portion of one; it is well ridged concentrically, and the nodes are moderately elevated. The specimens seen in the rock seemed decidedly smaller than the recent form and had the outer lip relatively thicker.

Fasciolaria cf. *tulipa* Linn.

Badly preserved casts may be of this species.

Ficus (?) sp.

A cast of the apical part of a gasteropod with spiral ribs crossed by fine set growth-lines, giving it a closely reticulated appearance, may be a small form of *Ficus*. It occurred in hard dull brecciated limestone, close to the igneous rock on the north-east side, at an altitude of about 650 feet. The limestones having been altered by the intrusion, none of the accompanying fossils were identifiable.

Oliva cf. *reticularis trochala* Woodring. Pl. XV, Fig. 8.

An olive from the white chalky rock appears intermediate between the above Bowden species and the living *O. reticularis* Lam. It closely resembles Woodring's[1] figure (pl. xiii, fig. 4), but the inner lip is less plicated posteriorly than in the Bowden, but more so than in the recent species, and the outer lip is thicker than in my specimens from Bowden.

Natica (*Polinices*) cf. *subclausa* Sow.

Two specimens of *Polinices* occurred in the white chalks, one is 21 m. high and 18 mm. wide. The shell is more solid and has a thicker and stronger callosity on the posterior part of the umbilicus than has the living *P. uberina* d'Orb. The smaller specimen resembles a Bowden specimen of *P. subclausa*, but the spire of the Brimstone Hill specimens is more drawn out and extended. They look like a variety intermediate between *P. subclausa* and the recent *Natica porcellana* d'Orb., or *N. uberina* d'Orb., that one finds on the West Indian beaches.

Bulla cf. *vendryesiana* Guppy. (GEOL. MAG., 1874, 4. Pl. XVI, Fig. 6.)

Eight specimens of *Bulla* occurred in the chalky rock, the largest is 29 mm. long and 18 mm. wide. The two larger specimens rather resemble the living *B. maculosa* Mart. from the West Indies but the Brimstone Hill fossil is more dilated anteriorly. Smaller examples are solidly built and apparently adult and resemble Woodring's figure of the above species from Bowden (pl. ii, fig. 20). One of them has fine growth-lines and smooth growth-bands. All seem to be varieties of one species, probably *V. vendryesiana*, which Guppy says is allied to *B. striata* Brug., particularly to that form called *B. maculosa* Mart.

Ostrea (*Lopha*) cf. *paramegodon* Woodring.

Oysters, or fragments of oysters, the largest 31 mm. long and 25 mm. wide, of irregular shape and outline, occur in ashy limestones with Pectens of the *zic-zac* type, near the intrusion on the north-west side. The shells are thin, two right or attached valves are concave, one rather strongly so, the left valves are flattened but irregular, and show traces of large, flat, incipient folds. The hinge area is triangular in one right valve, beaks are more or less twisted, growth-lines are well marked, and the margin of each valve near the hinge is rather strongly dentated.

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[1] *Marine Mollusks from Bowden, Jamaica*, pts. i and ii. The Carnegie Institution of Washington, 1925–8.

The only living shell I can compare them with is the young stage of a variety of *Ostrea megodon* Hanley, from Peru, and according to Woodring from Lower California. They resemble perhaps more the young stage of *O. paramegodon* Woodring, a Bowden fossil, but the Brimstone Hill specimens are smaller than Woodring's figures (pl. vi, figs. 12–14).

Glycimeris pallium Reeve. Pl. XV, Fig. 4.

A small thick valve, with strong hinge plate, agrees with recent specimens of the above, but the living form seems to have fewer ribs.

Glycimeris oculatus Reeve.

Several valves from the chalky beds with colour markings agree with specimens of this species that one finds on the shore at St. Kitts.

Glycimeris cf. *pennacea* Lam.

Six Pectunculids from the chalky beds are all about the same size, 34 mm. in diameter, the shells rather thick with a strong hinge plate. One has the beak erect and rather medially situated, the outline almost circular and the area amphidetic. It looks like a specimen of *G. pennacea* Lam. In the other five the beak is situated rather behind the median line, and is forwardly directed, the area being nearly all behind the beak, and the anterior margin of the shell is drawn out and angulated, as it is in some recent specimens of *G. decussatus* Linn. and *G. pennacea* Lam.

One of the Brimstone Hill specimens resembles a figure of the Bowden form, *G. prepennacea* Woodring (pl. ii, fig. 6), but is larger. Woodring separates *Glycimerella* and *Glycimeris* on the question of the opisthogyrate umbos and opisthodetic ligament (*Miocene Moll. from Bowden*, 1925, 24–7).

Arca (*Scapharca* or *Anomalocardia*) cf. *deshayesi* Hanley, var. 1.
Pl. XV, Fig. 11.

About twenty-five ribbed arcas were collected in the outer chalks on the west side of the hill. They are well preserved, often with both valves present, but are variable. Possibly they may all be varieties of one species, but seem to fall into about four different groups, and appear to be intermediate between Bowden fossils and the recent species that one collects on the shore at St. Kitts.

Variety 1. Valves, when fully grown, very deep, the area wide and concave, marked with numerous rather wavy incisions. Some of the shells are very thick and senile, and the space for the animal consequently very narrow. Towards the margin, coarse and irregular growth interruptions appear. Ribs number about thirty-two and are rounded and rather narrow, the sulci between them are wide and shallow. Near the edge of the posterior margin the growth-lines become foliaceous, and at the anterior end the ribs tend to carry a shallow groove. A double valved specimen is 62 mm. long, 46 mm. high, and 52 mm. across both valves; the great depth is due to the wide concave area, 16 mm. across. This form is evidently related to the recent *A. deshayesi*, but the living form has only about twenty-eight ribs, which are relatively broader, and the Brimstone Hill fossils do not have the upper posterior alation often seen on *A. deshayesi*. They may be descendants of the Bowden shell *Diluvarca halidonata halidonata* Dall (Woodring, *Bowden Mollusca*, pl. iv, figs. 3 and 4).

Arca (*Scapharca*) cf. *deshayesi* Hanl., var. 2. Pl. XV, Fig. 10.

Another variety, of which I have five specimens, is 53 mm. long, 39 mm. high, and the right valve is 17 mm. deep, being much thinner and less inflated than the last form. The area is narrow and inconspicuous and bears a few straight incisions. Ribs are about twenty-eight in number, and are rather wide and flattened, the anterior ten or eleven ribs are grooved down the middle and towards the posterior end and on the rounded ridge the ribs become wide and flat and near the margin carry two or three shallow grooves. The growth interruptions are not conspicuous. These forms recall in shape the Bowden fossil *Diluvarca prephina* but are larger (Woodring, *Bowden Mollusca*, pl. iv, fig. 8). Some of them are not unlike *Scapharca guayubinica* Maury from the Haitian beds.

Arca (*Scapharca*) cf. *deshayesi* Hanl., var. 3. Pl. XV, Fig. 9.

A single right valve is 53 mm. high, 41 mm. long, and 19 mm. deep, and has thirty ribs well rounded with well scooped sulci about equal in width to the ribs. The anterior five ribs each carry a narrow groove and the ribs do not widen much posteriorly. The shell is solid and has a slight posterior alation. The ribs are rather like those on the recent *A. deshayesi* but are more numerous, there being twenty-seven or twenty-eight on the recent form. The general shape is that of the Bowden forms *Diluvarca perplura* Woodring or *D. prephina* Woodring (*Bowden Mollusca*, pl. iv, figs. 7 and 8).

Arca (*Scapharca*) cf. *secticostata* Reeve, var. Pl. XV, Fig. 12.

A left valve is 38 mm. high, 58 mm. long, and 19·5 mm. deep. Ribs are twenty-eight in number, and are narrow and well cut, and widen on the lower posterior part where they carry one, increasing to three, grooves; the anterior ribs are sharp, and have one groove. The intervening sulci are wide and gently scooped. The area is flat and has straight incisions in front but wavy ones behind; the shell outline expands posteriorly. This shell has the general shape of the Bowden form *Diluvarca inaequilaterialis* Guppy (Woodring, *Bowden Mollusca*, pl. v, figs. 1–3), but is much larger and more inflated. It is also comparable with *Scapharca margaretae* Maury (*Bull. Am. Pal.*, 29, 1917, pl. xxviii, fig. 1). Among the living forms it comes nearest to *Arca secticostata* Reeve.

Arca cf. *imbricata* Brug.

A cast of a valve apparently of this species in hard white limestone.

Pecten cf. *bowdenensis* Dall. Pl. XV, Fig. 7.

Four specimens from coarse, ashy limestones near the igneous rock on the north-east side resemble in general features the living *P. zic-zac* Linn., but the right valve is much more arched and inflated and the ears are relatively smaller. The nineteen or so broad ribs are flatter and are separated by more finely cut grooves. The right valve resembles closely specimens of *P. bowdenensis* figured by Woodring (pl. vii, fig 9). The concave left valve is more concave than in *P. zic-zac*, and is thicker and stronger, the ribbing is more like that on *P. zic-zac*, and the ribs are finer and less regular than in *P. bowdenensis*. Width 48 mm., height 44 mm, depth of right valve 24 mm.

Chlamys (*Plagioctenium*) cf. *nucleus* Born.

Several valves of Pectens with valves sub-equally inflated occur in the white chalky beds. Three larger ones, 45 mm. high, have a general resemblance to the recent *Chlamys gibbus* Linné (?=*dislocatus* Say) from Florida or *Chlamys nucleus* Born of the West Indies, but in the fossils the valves are more inflated towards the beaks, the ears are smaller, the ribs lower, and the grooves between them shallower. The smaller specimens, 15 mm. high, compare with *Chlamys* (*Plagioctenium*) *concinnatus* Woodring or *C. ameleus* Woodring (pl. viii, figs. 8 and 9) from the Bowden beds.

Chlamys (*Aequipecten*) cf. *plurinomis morantensis* Woodring.
Pl. XV, Fig. 3.

Six Pectens seem to agree in shape and ornamentation and size of the ears with the above species from Bowden (Woodring, pl. viii, figs. 4 and 5). The Brimstone Hill fossils, however, are larger. They also resemble *Pecten thetidis* Sow., as figured by C. W. Cooke (*Tertiary Mollusca of the Leeward Islands and Cuba*, pl. xi, figs. 4–6). The nearest living West Indian species seems to be *Chlamys exasperatus* Sow., but this has less inflated valves and narrower ribs and deeper sulci than the Brimstone Hill fossil has.

Pecten cf. *excentricus* Gabb.

Well-preserved double valved specimens 46 mm. high, 45 mm. wide, and 29 mm. in diameter, with traces of colour resemble this species as figured by Miss Maury (*Bull. Am. Pal.*, 29, pl. xxxiv, fig. 8). She remarks on its general resemblance to the living *Pecten irradians* Lam., but in the Brimstone Hill specimens the valves are much more inflated near the beaks, the ears, especially the posterior one, are small, the lower anterior shell margin extended and the ribs and interspaces more flattened.

Cardium (*Fragum*) *medium*, Linn., var. *christopheri* nov.
Pl. XV, Fig. 5.

A *Cardium* with both valves well preserved, 52 mm. in height, 51 mm. in width, and 52 mm. in thickness of both valves, occurred in the chalky beds. The beaks are relatively large, high, and inflated, more so than in *C. medium*; the posterior surface more concave and bounded by a broad angulation, carries a low and broad rounded ridge. The anterior and lower margin is regularly rounded without concavity, the lower hinder margin is only slightly produced, and the hinder margin has a slighter concavity than *C. medium* has. There are thirty-eight regular ribs on the surface, well cut and separated by deep grooves, the outer layer is formed near the margins of the shell by small lunular shaped growth protuberances which join one another across the grooves. On a recent specimen of *C. medium* there are thirty-six ribs and the growth protuberances do not join. *C. medium* is recorded by Woodring from the Bowden beds of Jamaica, but only about half the size of the living form.

Cardium (*Fragum*) cf. *burnsii* Dall. Pl. XV, Fig. 6.

Small angulated valves up to 13 mm. wide occur in the chalky limestones. There may be more than one species, and some look like the young of a form of *Cardium medium*. Others resemble Dall's species from the Chipola beds of Florida, and some are like *C.* (*Fragum*) *elattocostatum* Woodring (*Bowden Mollusca*, pl. xix, fig. 7), but have a less angular lower margin. *Cardium* (*Trigonocardia*) *sambaicum* Maury (*Bull. Am. Pal.*, 1917, pl. xxxvi, fig. 7) is similar, from the Haitian beds. *Cardium graniferum* Sow. from Panama, an analogue on the Pacific side, resembles in shape the Antillean shell but has fewer and stronger ribs.

Cardium (*Laevicardium*) *serratum* Linn.

Three casts apparently of this species, the largest 58 mm. high, 54 mm. wide, and 47 mm. across the valves, were collected in the chalky beds on the west side of the hill.

Chione cancellata Linn. var. *christopheri* nov. Pl. XV, Fig. 15.

Four specimens of *Venus cancellata*-like shells from the outer chalks of Brimstone Hill differ markedly from the living West Indian form. A large valve is 43 mm. long, 36 mm. high, and about 15 mm. deep. The concentric ribs are much less regular than on *V. cancellata*, and in the adult shell the ribs near the margin suddenly become very close together. Also the lower posterior margin of the shell is much more prolonged than in the recent form. The concentric ribs on the Brimstone Hill specimens are more frilled, and the spaces between them bear forwardly curved radial ribs which cause the frilling of the concentric ribs. The escutcheon is broader and deeper, and the angle of the ridge that borders it more acute than in the living form.

The differences would perhaps make a " specific " distinction, but on examining the forms of this shell that occur in the Coral rock of Barbados, I find they are very like a young shell from Brimstone Hill except that the latter has more frilling of the ribs. This frilling gives it a resemblance to the Bowden species *Chione woodwardi* Guppy (Woodring, pl. xxii, figs. 1–4), but Bowden specimens I have are smaller and shorter and have more closely set ribs.

Fully grown specimens from Brimstone Hill are very like specimens of corresponding size of the Pacific analogue *Venus* (*Chione*) *succincta* Valenc. (= *californiensis* Brod.), from California except that in the fossil the concentric ribs are more crowded together near the margin, and the lunule is rather smaller. The Pacific species grows to a greater size however, while young specimens of the Brimstone Hill fossil are more like the Antillean *V. cancellata.*

Venus (*Chione*) *paphia* var. *christopheri* nov. Pl. XV, Fig. 14.

Seven shells of the *Venus paphia* type occurred in the chalks on the west side ; the largest is 47 mm. long, 39 mm. high, and the valve 14 mm. deep. Young specimens are short and squat in shape, like the adult living shell, but have more regular and closer set ribs passing into scaly frills near the hinder ridge. After attaining a length of about 26 mm. the anterior and hinder margins become much produced and the later ribs grow very irregularly, often the broad ridges merge into one another, or irregular narrow and sharp ridges are developed with their edges turned upwards. Both lunule and escutcheon seem wider and deeper than in the living shell. Some of the specimens grow very like the Bowden species *Chione hendersoni* Dall. (Woodring, *Bowden Mollusca*, pl. xxii, figs. 7–10) but in the Brimstone Hill shells the earlier ribs are closer set and the later ones much less regular in growth than in the Bowden form. Smaller specimens resemble *Chione hendersoni* Dall as figured by Miss Maury from the Dominican Republic (*Bull. Am. Pal.*, 29, pl. xxxvii, fig. 8).

Cytherea sp.

A specimen, with both valves present but broken, was collected in the chalky beds, and is 42 mm. long, 31 mm. high, and 20 mm. across the valves, and the surface is smooth with concentric coloured growth bands. It differs from the living *C. maculata* Linn. in being more elongate, the valves rather more inflated, and the beak more anterior, and the slopes behind the beak and near the lunule more abrupt. *Cytherea albida* Gmel., living in the West Indies, seems to be a related form. The Bowden fossil *C. planiveta* Guppy has a much more concentrically grooved surface than the Brimstone Hill form.

Codakia cf. *imbricatula* C. B. Ad. Pl. XV, Fig. 2.

Five specimens, the largest 23 mm. high, 25 mm. wide, and 13 mm. in diameter, come near the above living species from Bermuda and the West Indies. The Brimstone Hill fossils are not so inflated as the recent form often is, and the curved radiating ribs are coarser and fewer especially towards the hinder margin and the growth interruptions more marked and more widely spaced.

Codakia (*Jagonia*) cf. *vendryesi* Dall.

Three well-preserved valves of this small species occurred in ashy beds near the igneous rock on the north-west side. The largest is 11·5 mm. in diameter, and 4·5 mm. deep. The sculpture agrees with the above Bowden species, which is figured and re-defined by Woodring (*Mioc. Moll. from Bowden*, 109, pl. xiv, figs. 1–4), but the Brimstone Hill fossil is rather larger. The recent analogue of this species is *Lucina costata* d'Orb (= *L. antillarum* Reeve) and is about the same size but less strongly sculptured than the fossil from Brimstone Hill.

Codakia near *C. orbicularis* Linn. Pl. XV, Fig. 1.

Two specimens, one a single valve 46 mm. high and 52 mm. wide, resemble in general characters recent specimens of *C. orbicularis* Linn. or *C. tigerina* Linn. The divergent ribs in the Brimstone Hill fossils, however, are more even and regular and less wavy and are crossed by more strongly incised growth-lines, giving a more pronounced reticulation, and making the protuberances on the surface sharper and finer, causing them to be almost prickly towards the margin. Also if these specimens are fully grown they are much smaller than large specimens of the living form. The living Indo-Pacific analogue *C. tigerina* Linn. (= *C. exasperata* Reeve) seems to have fewer and more rounded and coarser protuberances than the West Indian form which should apparently be called *C. orbicularis* Linn.

Divaricella cf. *prevaricata* Guppy.

Two specimens occurred in the chalky beds, the larger is 14·5 mm. wide, 13 mm. high, and 9 mm. across both valves. The divaricate ribs are more numerous, closer set, and less regular than on specimens of the common living West Indian shell *D. quadrisulcata* d'Orb. and they resemble rather closely Woodring's figures of the above Bowden form (pl. xvii, figs. 9 and 12).

Phacoides (*Linga*) cf. *podagrinus* Dall.

Five specimens were collected in the chalky beds; the largest is a single rather flat valve, 38 mm. wide and 36 mm. high, and resembles the common living *Lucina pennsylvanica* Linn. Three other double valved examples are smaller and more inflated, and have the anterior margin drawn upwards and narrowing rather rapidly.

A much smaller double valved specimen has the valves rather flat. All seem to be varieties of one species but do not attain the size of the recent *L. pennsylvanica.*

Lucina (*Phacoides*) *jamaicensis* ? Spengl.

Eight specimens of a Miltha-like shell occurred in the white chalks. The outer layer is destroyed leaving not the cast but an inner layer, making determination uncertain. On the inner layer are curved radiating lines besides traces of outer growth foliations. The largest is 79 mm. long, 76 mm. high, and 45 mm. across both valves. It seems probable they are casts of the above living West Indian shell or some variety of it.

Lucina (*Phacoides*) *aurantia* Desh. Pl. XV, Fig. 17.

A well-preserved specimen 23 mm. high, 23 mm. wide, and 15 mm. across the valves, agrees with this living but rare West Indian species. The concentric sculpture is stronger on the right than on the left valve.

Diplodonta rotundata Montagu.

Two specimens in ashy chalks near the igneous rock with Pectens of the *zic-zac* type and *Ostrea* cf. *paramegodon*. They are very like valves picked up on the shore at Barbados. They are 20 mm. high, 20·5 mm. wide, and the two valves 13·5 mm. across.

Diplodonta cf. *semiaspera* Phil.

A small rounded shell 10·5 mm. long, 9·5 mm. high, and 6 mm. across the valves may belong to this species recorded living off St. Thomas. The valves are finely punctate under a lens.

Capsa (*Metis*) cf. *intastriata* Sow. Pl. XV, Fig. 13.

Four well-preserved specimens from the outer chalks on the west side of Brimstone Hill resemble in shape this species labelled "Mexico" in the British Museum. I have a recent shell of similar shape from Bermuda, but the Brimstone Hill fossils have more regular, less wavy, sharper, and better marked growth-lines. The growth-lines are more like those on a recent specimen of *Capsa lacunosa* Chem. from West Africa, but the African shell is shorter and more inflated. *Capsa ephippium* Spengler from the East Indies is a very similar shell.

Tellina (*Arcopagia*) *fausta* Pult.

Casts of a large *Tellina* may be this common West Indian species.

Tellina (*Tellinella*) *interrupta* Sol.

Two specimens resemble this living Antillean form but the Brimstone Hill fossils have more regular, sharper, and more widely spaced growth-lines and a less acute posterior prolongation of the valves.

Tellina (*Semele*) near *proficua* Pult.

A single valve may belong to this living West Indian species.

Tellina (*Angulus*) cf. *similis* Sow. Pl. XV, Fig. 16.

A small double valved slightly gaping Tellinoid shell 19·5 mm. long, 12 mm. high, and 5·5 mm. across the valves, may be this form, which lives off St. Vincent, but the beak seems more medially situated in the fossil than in the recent form.

Gastrochaena cf. *cucullata* Desh.

Imperfect casts may belong to this living West Indian species.

EXPLANATION OF PLATES XIV AND XV.

PLATE XIV.

FIG.

1.—View of Brimstone Hill from the south, the main cone of St. Kitts lies to the right and the sea a little way to the left.

2.—Diagrammatic sketch of the above, showing the extent of the mantle of upturned sedimentary beds (L.L.) around the igneous andesitic plug (A.A.). The squares on the top indicate old fortifications.

3.—The upturned chalky sedimentaries (outer chalks) on the south-west side of Brimstone Hill leaning against and dipping away from the igneous core at various angles.

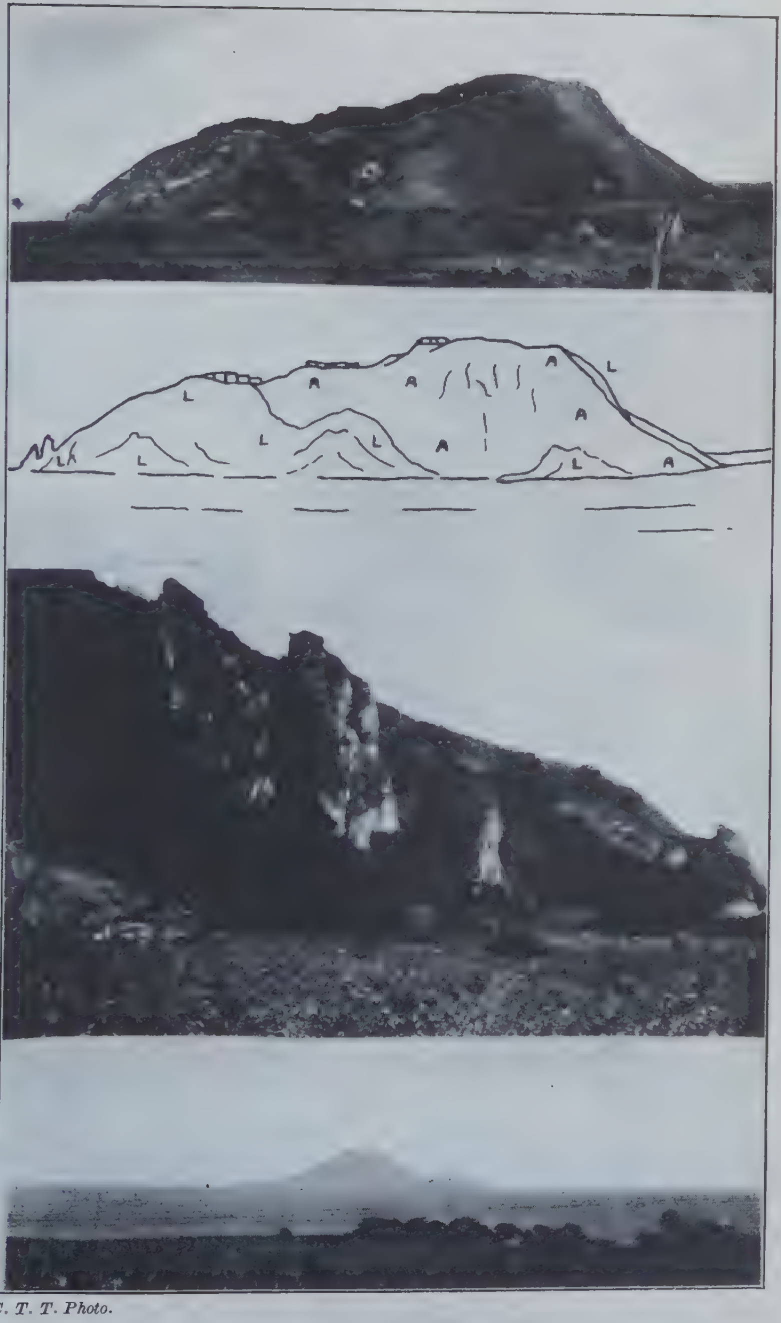
4.—A view taken from the north end of St. Kitts looking towards St. Eustatius and Saba. On the south-west side of St. Eustatius a patch of upturned sedimentaries, the White Wall, leans against the cone up to nearly half its height. Beyond on the right is Saba, a plain volcanic cone.

PLATE XV.

All except Fig. 6 are somewhat reduced in size.

FIG.

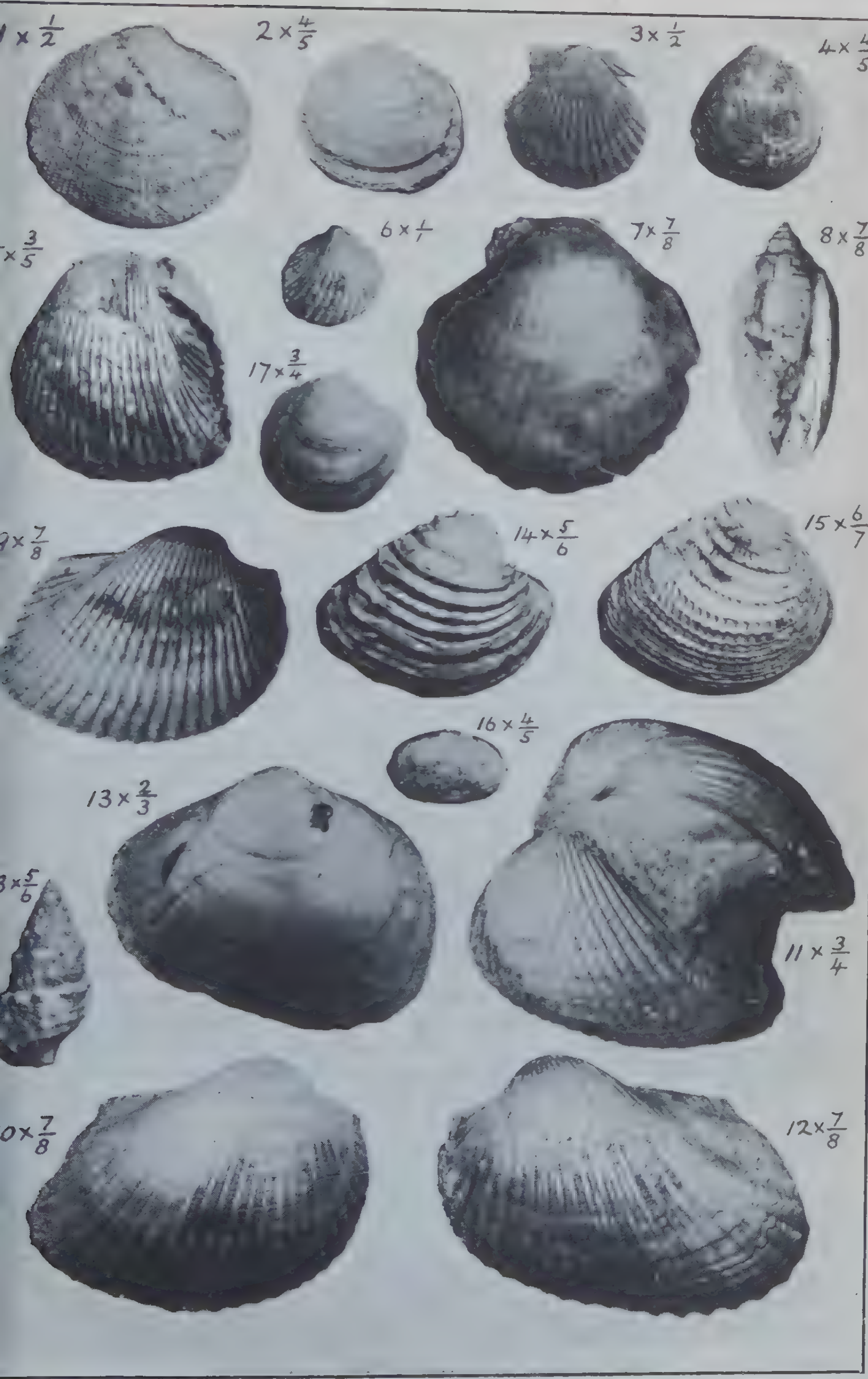
1.—*Codakia* near *C. orbicularis* Linn.
2.— „ cf. *imbricatula* C. B. Ad.
3.—*Chlamys* (*Aequipecten*) cf. *plurinomis morantensis* Woodring.
4.—*Glycimeris pallium* Reeve.
5.—*Cardium* (*Fragum*) *medium* Linn. var. *christopheri* nov.
6.— „ „ cf. *burnsii* Dall.
7.—*Pecten* cf. *bowdenensis* Dall. Right valve.
8.—*Oliva* cf. *reticularis trochala* Woodring.
9.—*Arca* (*Scapharca*) cf. *deshayesi* Hanl., var. 3.
10.— „ „ „ „ var. 2.
11.— „ „ „ „ var. 1.
12.— „ „ cf. *secticostata* Reeve, var.
13.—*Capsa* (*Metis*) cf. *intastriata* Sow.
14.—*Chione* cf. *paphia* var. *christopheri* nov.
15.— „ *cancellata* Linn., var. *christopheri* nov.
16.—*Tellina* (*Angulus*) cf. *similis* Sow.
17.—*Lucina* (*Phacoides*) *aurantia* Desh.
18.—*Cerithium litteratum* Born.



C. T. T. Photo.

VIEWS OF BRIMSTONE HILL, ST. KITTS (1, 2, 3), AND OF ST. EUSTATIUS (4).

[To face p. 258.



. T. & T. S. W. *Photo.*

MOLLUSCA FROM BRIMSTONE HILL, ST. KITTS.

DESCRIPTION OF ROCK SPECIMENS FROM BRIMSTONE HILL AND THREE OTHER LOCALITIES IN ST. KITTS, B.W.I.

By T. S. WESTOLL, Dept. of Geology, Armstrong College.

BRIMSTONE HILL.

References to the rock forming the hill will be found in papers by Spencer (1901, p. 536), Sapper (1903, p. 284, 1904, p. 41), Earle (1925, p. 11), and Wayland Vaughan (1926, p. 349).

Spencer and Earle describe the hill as being composed of tuffs and ashes (with limestone, etc., round the outside). Earle describes specimens as fine-grained, consolidated, hard grey ash, consisting almost wholly of lath-shaped felspars, with a general banded arrangement, and of all sizes, and a little black granular iron ore : they are stated to differ from a true andesite in little but the absence of ferro-magnesian minerals and the more markedly banded arrangement of the felspars, and the rock is described as an andesitic tuff. Vaughan gives a determination (by Iddings) of specimens from 360 ft. and 400 ft. altitude on the north side as pyroxene-andesites, while Sapper (1904, p. 41) gives a determination (by Bergeat) of rock from Brimstone Hill as an augite-andesite.

The specimens brought back by Dr. Trechmann are from " near the top ", " 400 ft. alt., N. side ", and " top of hill ". One other specimen was left at the British Museum (Natural History) and I am indebted to Mr. W. Campbell Smith, M.C., M.A., Sec.G.S., for the loan of a slide prepared from this. All the rocks are hypersthene-andesites with very subsidiary and sporadic hornblende and augite.

NEAR THE TOP.

The hand-specimen is light-grey in colour, weathering to a thin brownish crust. It is fine-grained and shows a few small phenocrysts of felspar up to 2 mm. long and a few pieces (up to 1 mm. long) of dark minerals with good cleavage. Under the microscope the rock is seen to contain microphenocrysts of felspar, with rare hypersthene phenocrysts (both of them glomeroporphyritic). Hornblende is very rare. The general groundmass consists of small felspar laths, hypersthene prisms, and grains of magnetite in a sparse glassy base. The structure is microporphyritic and the marked parallel arrangement of felspar laths and hypersthene prisms gives the section a trachytic aspect.

The felspar is *plagioclase*, occurring as phenocrysts (either simple or glomeroporphyritic), and also as laths (often with " skeleton " terminations) in the groundmass. The phenocrysts are clear, idiomorphic, and show well-marked basal cleavage. They show well-marked zoning, with indications of only a few discontinuities. Twinning is sometimes complex : Carlsbad and some albite twins are present among the phenocrysts—though only a few show good albite twin lamellae. Some of the felspars have inclusions (of hypersthene, etc.) often set parallel to the basal cleavage. The composition of the phenocrysts varies from *c.* Ab_{20} An_{80} at the core to Ab_{50} An_{50} at the margins. The laths of the second generation are near to Ab_{55} An_{45}. The range is thus from bytownite to andesine.

The *hypersthene* occurs in small granules and prisms in the groundmass; a few phenocrysts, sometimes glomeroporphyritic, are also present. The latter have rounded corners but are otherwise fresh. Many of the prismatic needles have a rough, almost basal fracture: the phenocrysts have good prismatic cleavage. Pleochroism is well-marked and in sections of usual thickness it is

$$\left.\begin{array}{l}X = \text{reddish yellow}\\ Y = \text{yellowish brown}\\ Z = \text{bluish green}\end{array}\right\}\text{ all pale but well marked.}$$

The crystals have the usual optical properties of a moderately ferriferous hypersthene: negative sign, positive elongation, straight extinction and the birefringence is about ·014.

Hornblende is very scarce in my sections, but in the specimen sent to the British Museum it is more abundant, though of extremely sporadic distribution. Crystals up to 3 mm. long were noted. These are brown in colour and are surrounded by a broad border of "spongy"-looking black iron oxide. The pleochroism of the hornblende is intense.

X. brownish yellow.
Y. very dark brown.
Z. very dark brown.

Magnetite occurs in small crystals and granules, often rather jagged in appearance, evenly distributed through the rock.

The glassy base is clear and has lower refractive index than Canada Balsam. Its distribution is rendered more obvious by gelatinization with conc. HCl and staining with fuchsin. The same treatment showed the basic cores of the felspars with sharp borders.

The rock is thus a hypersthene-andesite with rare hornblende and with trachytic structure. Slides of the rock are now in the collection of the Geological Dept., Armstrong College (W.I.1), and the structure is illustrated in Fig. 2*b*.

400 FEET ALTITUDE, N. SIDE.

This only differs in unimportant details from the last. The hand specimen is rather more friable. The grain-size is slightly, but appreciably, larger. Pyroxene phenocrysts with idiomorphic contours are seen to be composed of remnants of original hypersthene at the centre with a broad border consisting of a mosaic of small pieces of green augite, giving a good pseudomorph. The granulation is very fine at the margin (W.I.2).

TOP OF HILL.

The hand-specimen is light reddish-purple and somewhat friable. Under the microscope the grain size in the section is seen to be larger than in the other rocks from the hill. The hypersthene prisms, especially, seem to be much larger and are altered peripherally to a reddish brown substance, possibly an iron oxide. The pleochroism and birefringence of the remaining hypersthene are enhanced. The amount of iron ore in the groundmass is greater than the W.I.1 and W.I.2. In one of the slides a magnetite crystal of fairly large size and a crystal of pale augite are associated; the latter has a peculiar fibrous-looking rim. Slides of this rock in Armstrong College are listed W.I.3. the structure is illustrated in Fig. 2*a*.

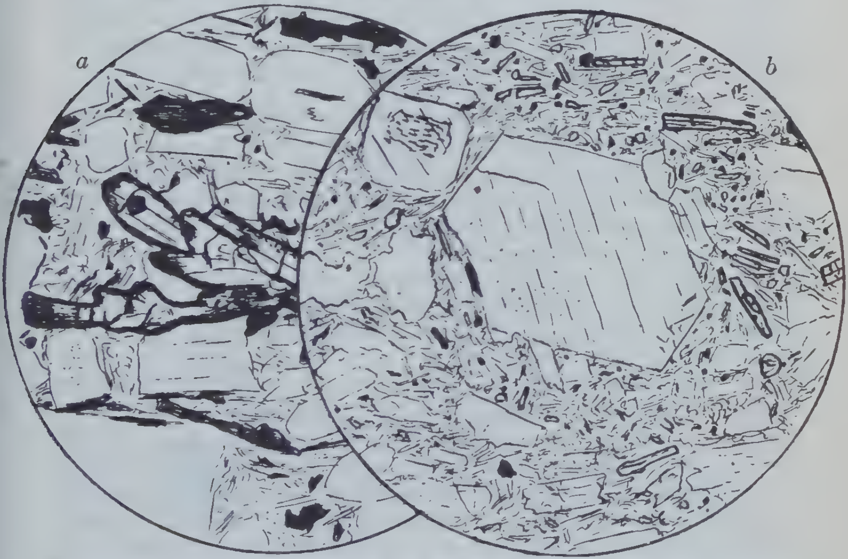


FIG. 2.—Andesites, Brimstone Hill, St. Kitts. *a*, Top of hill. Note altered hypersthene. Slide W.I. 3. × 60. *b*, Near top of hill. Idiomorphic felspar phenocrysts in groundmass of plagioclase laths, hypersthene prisms, etc. Slide W.I. 1. × 30.

The differences in texture of these rocks can be accounted for by differences in cooling conditions: the alteration of hypersthene to the iron oxide (?) is only seen in one section, and may be due to oxidation or to fumarole action (cf. Lacroix, 1904, p. 531, etc.).[1] The rocks are all hypersthene-andesites with very subsidiary augite and rare hornblende (the latter always with a corrosion-border) and a base with felspar laths, etc. and very sparse glass. They compare closely with the hypersthene-andesites of Mt. Pélée, especially with that variety with a microlitic groundmass (Lacroix, 1904, pp. 503–12).

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[1] Since writing the above, I have, through the kindness of Mr. W. Campbell Smith, been able to examine some of Dr. Earle's material. One of his slides, labelled "Top of Brimstone Hill" (number 1924. 12. 407), is closely similar to my own section W.I.3, except that it is slightly firmer in grain, and the alteration of hypersthene has gone almost to completion along these lines, and the red material is beginning to spread through tiny cracks in the rock. Thus the rock, using transmitted light, appears to be made up of plagioclase laths and iron ores only.

Small quantities of ashy limestone from the side of the hill, obtained in cleaning fossils, were treated with hydrochloric acid and the residual minerals were found to include *hypersthene* in well-shaped crystals with entire or jagged ends; splinters of brownish green *hornblende*; less common greenish *augite*; the most abundant volcanic constituent seems to be *plagioclase* felspar in idiomorphic crystals and cleavage fragments. No certain glass-fragments were seen. The limestone also contains small well-shaped *zircons* and partly rounded grains of *quartz*—probably of sedimentary origin. The locality of this material is given as "near the intrusion (or extrusion) on the N.W. side: with Pectens of *zic-zac* type".

NEAR BRIMSTONE HILL.

A specimen of rock from the north-west side of Brimstone Hill about 30 ft. from the base is also among those brought back. The hand-specimen is light in colour with 3 mm. felspar phenocrysts and ferro-magnesian minerals in prisms up to 5 mm. long. The groundmass is greyish and fine-grained.

In section the rock is seen to comprise phenocrysts of plagioclase and pyroxene in a groundmass of minute felspar laths, hypersthene crystals, and magnetite specks in a rather turbid—but isotropic—base of low refractive index.

The *plagioclase* exhibits very fine zoning indicating numerous stages. Twinning is often very complex, but albite and Carlsbad twins are usually present. The crystals sometimes show abrupt truncation across the zoning: this was thought, at first, to indicate clastic structure but the groundmass seems to be that of a typical lava with a glassy base. The plagioclase has inclusions of irregular bodies of glass, hypersthene prisms, etc., usually arranged concentrically. The composition of the phenocrysts ranged from *c.* Ab_{40} An_{60} at the centre to Ab_{55} An_{45} or Ab_{50} An_{50} at the margin. The laths are about Ab_{55} An_{45} in composition.

The *pyroxene* phenocrysts include both hypersthene and augite, both separately and in parallel growth (augite applied to (100) of hypersthene), cf. Lacroix, 1904, p. 506, etc. The hypersthene is similar in properties to that described in the rock from the hill itself. The augite is green and occurs in splinter-like crystals.

The groundmass includes minute felspar laths, hypersthene, and magnetite in a glass. There is no indication of flow structure.

The rock is a porphyritic pyroxene-andesite, differing from that of the main mass of the hill in having greater quantities of augite and hypersthene; in the structure of the felspars and in the indications of slight explosive action afforded by the phenocrysts. Slides W.I.4.: see Text-fig. 3*b*.

EAST SIDE OF ST. KITTS.

A light purplish-grey rock with felspar phenocrysts up to 4 mm. long; one or two grains of ferro-magnesian minerals. Microscopically the rock is seen to have numerous phenocrysts of plagioclase with rare ferro-magnesian minerals but with much iron ore in a groundmass of small plagioclase laths and iron ores, with small needles of a reddish mineral, set in a glass.

The *plagioclase* is idiomorphic or hypidiomorphic and is well zoned. The cores of the phenocrysts have the approximate composition Ab_{15} An_{85}, the margins about Ab_{55} An_{45}. The small laths have a composition near to Ab_{60} An_{40}. A short distance within the margin of many of the plagioclase phenocrysts is a layer of small needles (or sections of flat plates?) of a reddish-brown mineral set parallel to the edge of the felspar. This mineral seems to be slightly pleochroic but is in crystals too small for determination; it is probably, however, an iron ore mineral (see Text-fig. 3*a*).

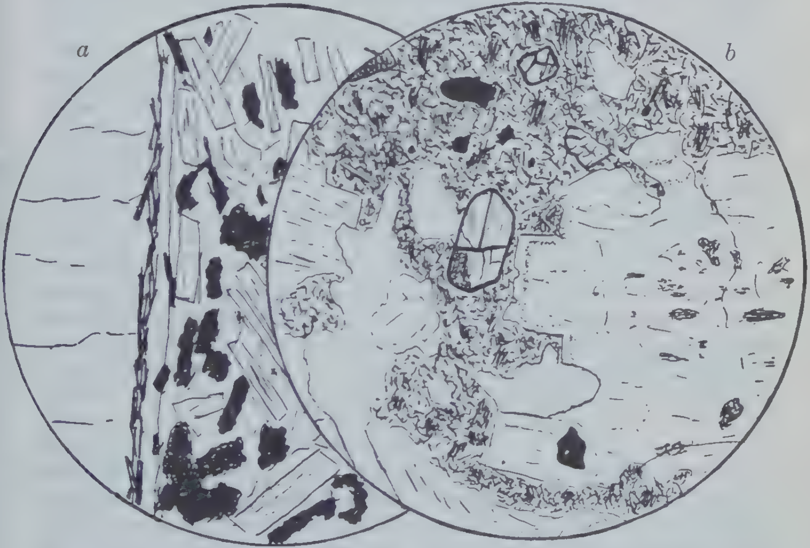

FIG. 3.—Rocks from St. Kitts. *a*, East side of Island. Plagioclase with inclusions parallel to border. Groundmass with iron oxide and felspar laths in a glass. W.I. 5. × 120. *b*, 30 feet north-west Brimstone Hill. Plagioclase with inclusions and hypersthene with augite in a groundmass (diagrammatic). W.I. 4. × 30.

One crystal of a reddish-brown augite (apparently impregnated with iron oxide) was seen to pass outwards into a black opaque substance, and this into red opaque iron oxide, including magnetite masses. In the groundmass are many well-shaped masses of red iron ore; these may be due to the formation of pseudomorphs or to a thick coating over some ferro-magnesian mineral.

The sections (W.I.5) are comparable in many ways with those from the top of Brimstone Hill (W.I.3), but there is more glass, the felspars of the ground are smaller, and pyroxene, if present at all, is thickly coated with iron ore. There has been growth of the felspars since the first formation of reddish iron ore (?).

The rock is apparently an andesite altered in some way or other, possibly by oxidation. The form of occurrence, according to Dr. Trechmann, is that of a lava-flow.

BLACK ROCK, ST. KITTS.

This locality is on the north-east coast of the island and gets its name from the occurrence of a flow of olivine-basalt. The rock was determined by Bergeat (in Sapper, 1904, p. 40) as an olivine-rich felspar-basalt: by Lacroix (1904, p. 581) as a "labradorite" with olivine but no hypersthene. Spencer (1901, p. 536) also mentions it as a black basalt flow.

The hand-specimen from Dr. Trechmann's collection is dark and heavy, with felspar phenocrysts up to 3 to 4 mm. long. It is otherwise fine-grained, with small, hollow, ragged cavities. Microscopically the rock is seen to consist of phenocrysts of plagioclase, pyroxene, and olivine with granular magnetite in a dark purplish-brown glass full of minute black specks of iron ore and felspar laths.

The felspar is wholly plagioclase and is strongly zoned. Its composition is Ab_{30} An_{70} at the centre, the thin outer core having a composition *c.* Ab_{60} An_{40}. Olivine occurs in grains of medium size, often idiomorphic, and with quite good cleavage. The pyroxene is a light-green augite with high extinction angles. Magnetite occurs in irregular small granules.

The rock is an olivine-basalt, with a glassy base.

ACKNOWLEDGMENTS.

I have to thank Prof. G. Hickling for allowing me to study these rocks at Armstrong College, Mr. G. S. Mockler, B.Sc., for much helpful information and advice, and Mr. W. Campbell Smith, M.C., M.A., etc. for the loan of a slide prepared from one of Dr. Trechmann's specimens. I am indebted to Dr. C. T. Trechmann for placing these interesting rocks at my disposal.

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Age-Problems of the Lundy Island Granites.

By A. T. J. Dollar, B.Sc., A.K.C., F.G.S.

A RECENT communication from Mr. E. H. Davison relating to the possible age of the "Lundy Island granite" is interesting as affording several points of contrast with the results of detailed researches in structural and petrological characters of this somewhat inaccessible island in the Bristol Channel, which the author has been carrying out for some time.

His paper, which appeared in the Geological Magazine for February, deals with the chief chronological problems that Lundy has to present and is the most recently published addition to a study which has been prosecuted somewhat intermittently over a period of nearly a hundred years by several workers, including Sir H. de la Beche, R. Etheridge, and, lately, Mr. T. C. F. Hall, whose investigations in this locality have not yet appeared in print.

The premises and deductions that Mr. Davison has brought forward are essentially based upon only two criteria, viz. mineral assemblage and the mean diameters of pleochroic halos, which are apparently regarded by him as sufficient to support the view that "the Lundy Island granite" is of post-Carboniferous and pre-Tertiary age; but some ambiguity may arise in the interpretation of this suggestion unless certain facts, other than those which he mentions, are recognized and given due consideration.

Actually there are several chronological criteria in addition to those of mineral assemblage and mean diameters of pleochroic halos that are worthy of consideration before a scientific estimate connected with the dates of these rocks shall be as free from ambiguity as any worker can hope to make them under the circumstances.

In the first place, the plutonic intrusion which constitutes 94 per cent of Lundy is apparently *composite*; that is to say, several distinct granites are recognizable, each of which seems to have had its own particular development in time and space. This implies that to speak of age, or any other feature, in relation to *the* Lundy Island granite, is misleading.

Briefly, the present island forms part of a small igneous complex, involving both acid and basic rock types, with which are associated the remnants of certain altered shales and grits. The ages of both these components is still uncertain, and correlation of the sediments is complicated by their metamorphosed state.

In a review of mineral assemblages exhibited by granitic rocks from Lundy, the west of England, north-east Ireland, and the Inner Hebrides, Mr. Davison ignores the beryl of Lundy (1),[1] which mineral is more characteristic of rocks such as the granites of Mourne than of those assigned to a pre-Tertiary period, as was indicated by Dr. Brammall with reference to the beryllium content of Armorican granites (2). No mention is made of the ores of silver, copper, zinc, and iron, unmistakable traces of which are to be found with ores of tin in parts of the Lundy granites. This mineral association has its counterpart in Cornubia, but not among Tertiary rocks of the northern British Isles. Further, it is somewhat surprising to find that while sphene is listed as characteristic of " other minerals " in granites from Arran, despite its possible origin as a purely local contamination-product in assimilation zones of a magma, yet no reference is made to the red euhedral garnet, of equally suspicious origin, which is so common throughout granites on the summit of Lundy Island and parts of Dartmoor.

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[1] Figures in parentheses refer to references at end of article.

A careful measurement of fifty-nine pleochroic halos about zircons in biotite reveals the fact that their mean diameter is 34·9 microns, as compared with Mr. Davison's mean of 30·1 microns for twenty-four determinations of the same quantity. Methods advocated by Professor J. Joly (3) were employed throughout, and the sections investigated were representative of granites from all parts of the Island.

An extended account of researches is being prepared, but among other outstanding criteria affording direct or indirect evidence which bears upon the chronology of the Lundy granites the following are worthy of note :—

(1) Chemical.—The four analyses of these rocks which are extant would suggest that at least some of the latter are characterized by—

(*a*) The marked dominance of alkaline constituents (including lithia) over alkaline earths ;
(*b*) A relatively small proportion of lime, together with an even smaller amount of magnesia ; and
(*c*) Several rare constituents, including 0·1 per cent of beryllia.

This association of features, expressed in numerical form, shows a distinct similarity with that of the Mourne and Carlingford granites, a biotite-granite in Arran, a granophyre of Mull, and a hornblende-granophyre of Skye, though the presence of lithia in the Lundy mass is a fact which is not recorded in the analyses of these rocks, but a trace is present among certain types from Dartmoor, according to Dr. H. Harwood (4).

(2) Mineralogical.—The Lundy granites naturally reflect their chemical composition in exhibiting a predominance of orthoclase, perthite, and microperthite over plagioclase, but of special features may be noted :—

(*a*) The granular hypidiomorphic, or bipyramidal quartz, often crowded with inclusions, that is also found in the Mourne and Arran granites of presumed Tertiary age, and among Armorican elvans of Cornwall.

(*b*) The distinctly variable distribution throughout the mass of brown ragged biotite, which is the dominant ferromagnesian constituent in these rocks, and contrasts with the white lithia-bearing mica.

(*c*) Of accessory minerals not already mentioned, the widely disseminated iron ore is largely pyrrhotite, as was shown by Dr. R. H. Rastall and Mr. W. H. Wilcockson in 1915 (5).

(3) Textural.—Apart from a wide range of porphyritic fabrics, the most distinctive features are :—

(*a*) The granophyric and myrmekitic intergrowths of quartz and felspar.

(*b*) The drusy cavities lined with euhedral accessory minerals, which are common in many of the granites, particularly throughout junction-zones and pegmatitic facies, where

(*c*) platy fan-aggregates of micas, quartz, and felspar are common.

All these characteristics can be matched in the granites of Mourne and Arran.

(4) Structural.—Some evidence of indirect correlative value is afforded by tectonic and associated features.

For example, the dominant strike of sub-vertical joints is west–north-west, east–south-east, and parallel to this direction basic dykes have been injected throughout the south of the Island.

The latter are either basaltic, and often show tholeiitic affinities, or are coarser in grain and must be classed as dolerites which sometimes exhibit crinanite facies and amygdales, as was remarked by Dr. H. H. Thomas (6). Some orthophyres occur.

This essentially north-west–south-east trend accords with that of the Tertiary dyke-swarms in Scotland and Ireland, but is not uncommon in parts of Dartmoor also.

The association of basic dyke-swarms with complex intrusive bodies apparently reflects some distinct combination of crustal and magmatic conditions which still awaits a complete explanation.

Essentially north–south fissures in Lundy granites were filled by late micrognaitic or aplitic intrusive sheets, while, as in Arran, several basic dykes also follow these and many other divisional planes in the centre and north of the Island.

Detailed joint-analyses, coupled with a study of bathymetric contours, suggests that the initial Lundy intrusion was probably laccolithic, thereby agreeing with the assumed form of the original Scilly mass, which may be otherwise linked with the former through an hypothetical fault of Caledonian trend that may have provided a common inlet for magma in the two localities, according to C. W. Osman (7).

Crush-belts, of similar orientation to those in the Arran boss, are particularly well-developed across the central zone of Lundy Island.

(5) Geomorphological.—The present Island is overwhelmingly dominated by a level platform at 400 feet above mean sea-level, which is to be correlated with that on the mainland at the same height, and marks an upper limit of age for the intrusion. An immature drainage system with hanging valleys is also present.

In the foregoing account some attempt has been made to show how the plutonic intrusions of the Lundy complex share characters in common with both the Armorican rocks of Cornubia and those of Tertiary age in northern Britain and Ireland.

The intrusion in Tertiary times of a magma possessing Armorican characters might occur if palingenesis operated on a scale such as has been suggested by Professor A. Holmes (8).

Were this the case in the Lundy mass, several anomalies might be explained, including the large pleochroic halos, which could then be regarded as having been preserved in unfused micas of Palaeozoic initiation.

Though necessarily brief, it is hoped that enough has been said to demonstrate how the chronology of the Lundy granites is by no means clear.

There is still much in the data to be interpreted, and while trends of evidence and opinion may point to an essentially Tertiary age, it is probably still premature to assign any exact dates to this intrusive mass. However, in the near future there is hope that the hitherto unpublished investigations of Mr. T. C. F. Hall and that of the present author may contribute information which will afford either more weighty evidence in favour of one particular range of ages for these injections, or some explanation of the several conflicting features which they present.

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The Sub-Bothnian Unconformity (Finland).

By William J. McCallien, D.Sc., F.R.S.E., Glasgow University.

During the International Excursion for the study of the Pre-Cambrian held in Finland, July-August, 1931, a visit was paid to the outcrop of Bothnian conglomerates near Jaakkola, Suodenniemi, west of Tammerfors (Tampere). The excursion to Jaakkola was led by Professor Sederholm and Mr. Mikkola.

The question of these conglomerates has been dealt with in great detail by Prof. Sederholm in a memoir given over almost entirely to the subject.[1] In that work the history of the controversies about their origin and significance is given. From this we gather that at the end of the nineteenth century Sederholm's theory of a sub-Bothnian land surface west of Tammerfors met with more contradiction than approval. Later Sederholm himself was convinced of the intrusive nature of many of his junctions, chiefly through the work of Mäkinen.

Sederholm, however, correctly pointed out that the existence of conglomerates intercalated with the schists and containing pebbles and boulders of granodiorite prove beyond doubt that there are two different diorites, one older and one younger than the Bothnian sediments. Mäkinen thought that these two diorites did not differ much in age—that "one part of the diorite had consolidated earlier and had been broken into pieces which were later cemented together by the same intrusive masses and by schists which had remelted through the action of the diorite magma". It was generally felt that the theory of a sub-Bothnian unconformity had not stood the test of criticism.

In 1928, Sederholm entrusted Mikkola with the task of remapping the critical areas in Suodenniemi. The results of the resurvey may be quoted from the memoir referred to above. "The conglomerates containing pebbles of diorite were found to be more continuous than had been known before, and could be traced over larger areas. Further, not only tuffs of metabasaltic rocks but also effusive sheets of typical volcanic uralite-porphyrites were discovered. Dykes of metabasalt intersected the diorite at several places while other granodiorites were obviously later than the metabasaltic rocks. Thus new evidence was found that two diorites differing in age, existed in the region" (p. 15). Large areas of supposed contact rocks were discovered. In the neighbourhood of the schists the diorite was brecciated and the fragments cemented together by material not unlike that of the adjacent sediments. Mikkola thought that a refusion of the schists (palingenesis) had taken place. *Sederholm after recent examinations of the country is convinced that the breccia is a normal subaerially weathered one.* This is the thesis of Bull. No. 95.

As already mentioned the bulletin published in July was a preliminary one, and the final edition was published in November. The latter contains a lot of additional material in the text, fourteen extra text-figures, and a coloured map on the scale of 1/50,000. The new sections deal chiefly with the conglomerates at the southern boundary of the Bothnian schists and with the petrological description of the conglomerates and the comparison of the pebbles with the rocks south of the Bothnian schists.

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[1] "On the Sub-Bothnian Unconformity and on Archaean Rocks formed by Secular Weathering," by J. J. Sederholm, *Bull. Geol. Comm. Finland*, No. 95, 1931. A preliminary edition of the bulletin was published in July for the convenience of the excursion. Page references and text-figure numbers quoted here refer to the November edition.

The general structure of the Suodenniemi region is given in Bull. No. 95 from p. 17 onwards. Regarding the conglomerates of *large rounded* boulders of diorite the writer intends to say very little. They undoubtedly indicate the presence of pre-Bothnian land surfaces. Judging by the perfection of their rounding they are far-travelled boulders and they are not derived from the diorite in their immediate neighbourhood. They recall the Donegal and Scottish Dalradian conglomerates with nordmarkite boulders, the source of which is unknown. Just as in the Finnish occurrence the Donegal conglomerates were for long thought to be resting unconformably on the Donegal granite. Now it is clearly understood that the granite is intrusive into the Dalradians.

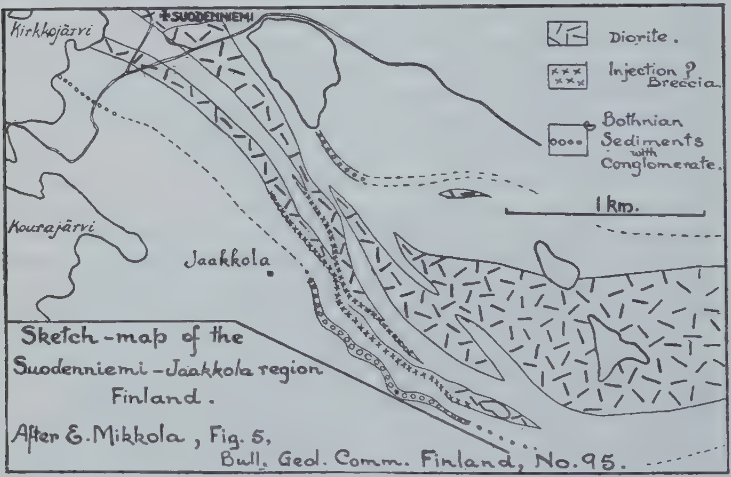
Kirkkojärvi
SUODENNIEMI
Diorite.
Injection ? Breccia.
Bothnian Sediments with Conglomerate.
1 km.
Kourajärvi
Jaakkola
Sketch-map of the Suodenniemi-Jaakkola region Finland.
After E. Mikkola, Fig. 5, Bull. Geol. Comm. Finland, No. 95.

FIG. 1.—Sketch-map showing distribution of Bothnian conglomerates, diorite, and breccias of doubtful origin E. of Jaakkola.

It is the Jaakkola breccia which interests the writer. Though it was agreed by some during the excursion that this breccia could have been a product of subaerial weathering, considerable doubt was expressed by the British geologists. A short distance from the outcrops of breccia a sharp contact was seen between the sediments and diorite with no sign of brecciation. It was at this locality that Fig. 2 was drawn and the present note is written primarily to show the nature of this junction. The diagram shows that it is not unusual for the diorite to send little tongues into the sediments. The sediments, which are of the nature of quartz-granulites with biotite, are current-bedded. *The current-bedding is rather difficult to find, but it indicates without doubt that the sediments nearest the* *diorite are younger than the sediments at a distance, or in other words that the diorite is younger, i.e., intrusive into the sediments.*

Fig. 23 of Bull. 95 is a map of a horizontal rock-surface showing the contact between "brecciated diorite" and "mica-schist" east of Jaakkola. This is believed to be the most interesting and distinct contact seen between the breccia and the schist. Sederholm says: "As we are aware there is, in this instance, no boundary at all between the schist and the cement of the breccia, and some fragments of diorite lie detached from the breccia entirely surrounded by the schist. Next to the contact, there are some slabs of diorite which are more continuous than at other places. At a distance of 1·5 m. from the contact there is, instead of masses of fragments, a less fractured mass of diorite, containing only sparse veins of the cementing schist, but N. of it breccia again occurs" (p. 35). "There is not the slightest sign of intrusion by the diorite. The schist shows a distinct bedding near the contact, but is otherwise absolutely similar to the cement of the breccia. As it is the same schist that contains a thick intercalation of conglomerate 70 m. more to the south its character of a true sediment cannot be doubted. If we wish to regard this schist either as a primary, or palingenetic eruptive mass, then we may as well ascribe a similar origin to the conglomerate! Nobody who has any respect for facts could, standing before this contact, explain it by assuming that the diorite was younger than the schist, or that the schist has been 'injected' in the diorite. It is a residual sedimentary breccia overlaid by a normal sediment in a slightly metamorphic condition" (p. 38). The mica-schist of this description and of the diagram in question is the same as the granulite of the present writer. In the diagram drawn by Mikkola the bedding is drawn as if in places there had been current-bedding which had escaped notice. The curved bedding-lines which are drawn hint at the diorite being younger than the granulite. The section will, therefore, not furnish convincing proof of the pre-granulite age of the diorite until the details of the succession are worked out from the current-bedding.

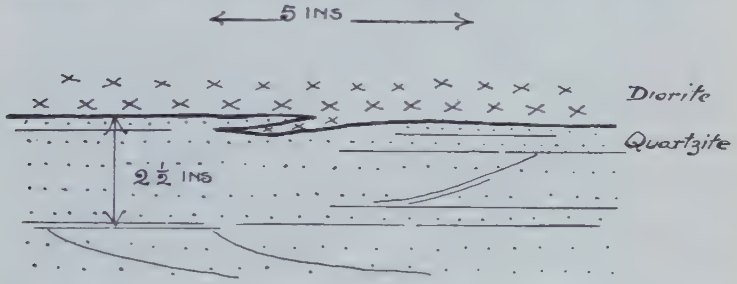

FIG. 2.—Plan showing relation of diorite to Bothnian current-bedded sediments E. of Jaakkola.

Sederholm says (pp. 40–1, Bull. No. 95) " Taking into consideration the evidence from the whole of this area, the proofs seem to be so complete that it may appear unnecessary toil to give the argumentation for this thesis in such detail. . . . On the other hand, the present writer has met so much contradiction of his arguments . . . that he is anxious to have these arguments[1] thoroughly refuted and the discussion, which has lasted more than thirty years, finally settled ".

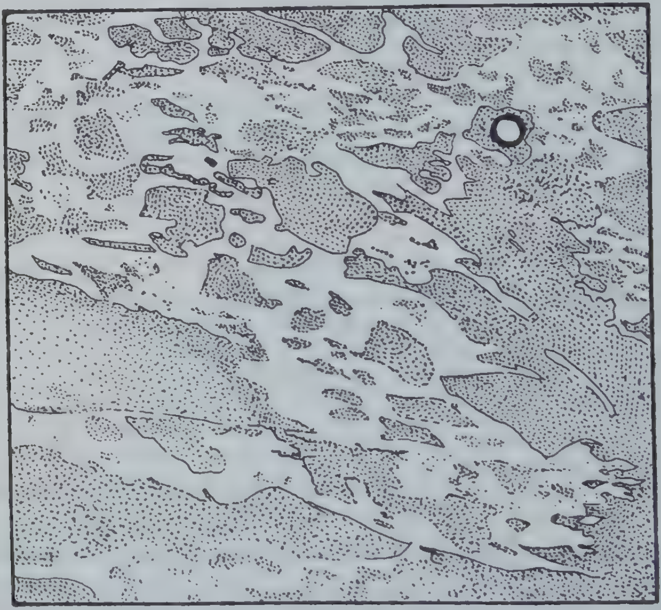

FIG. 3.—Breccia S.E. of Jaakkola, after fig. 19, *Bull. 95 Geol. Comm. Finland.* Dotted is diorite, clear is cement, and a coin is shown with black circle.

The evidence of the current-bedding in the diagram drawn by the present writer (Fig. 2) is unmistakable. A slice has been made of the diorite-sediment junction from the first exposure of the supposed mechanical contact visited. A mechanical junction is now thought to replace the old land surface in this part but the thin section indicates that the diorite is intrusive into the sediment. The argument of this note that the diorites of the Suodenniemi-Jaakkola district are *post-Bothnian* is only intended to apply to the localities from which the actual evidence is obtained, but it seems likely to the writer that most of the diorites indicated on Fig. 1 may be post-Bothnian.

Figs. 18 and 19 of Bull. No. 95 show surfaces of the Jaakkola breccia, and Fig. 3 of this note is a drawing of part of fig. 19. To the writer the breccia looks rather unlike a normal sedimentary breccia. Its characteristics might be adequately explained if it were an intrusive breccia. The supposed difficulties of this explanation are given by Sederholm.

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[1] Sederholm probably means the arguments of his opponents.

As in other cases, it cannot be denied that there existed land surfaces from which the conglomerates were derived. Without these large rounded boulders the Bothnian sediments themselves would, of course, indicate the same thing. Actual exposures of pre-Cambrian land surfaces are not so well preserved in Central Finland as they are in North-West Scotland where the relief of the Lewisian that existed in Torridonian times can be seen in the present landscape.

Bull. 95 is the result of long-continued field research by Prof. Sederholm and his assistants, and Mikkola's coloured map, which accompanies it, is an admirable production. The difficulties of mapping in Suodenniemi are many, and perhaps the greatest is caused by the carpet of moss which covers the rock surface. Most of the best exposures of Bothnian conglomerate seen during the excursion were stripped of their moss cover by Mikkola himself. The writer had so little opportunity of studying these rocks that he may be accused of belonging to that group of "ultrasceptical men of science", who, according to Sederholm, "refuse to believe even after they have seen the evidence." He feels justified, however, in suggesting that the solution of the problem lies in the current-bedding of the quartz-granulites and in the grading of the more typical Bothnian mica-schists, and that until these are studied all the evidence has not been utilized.

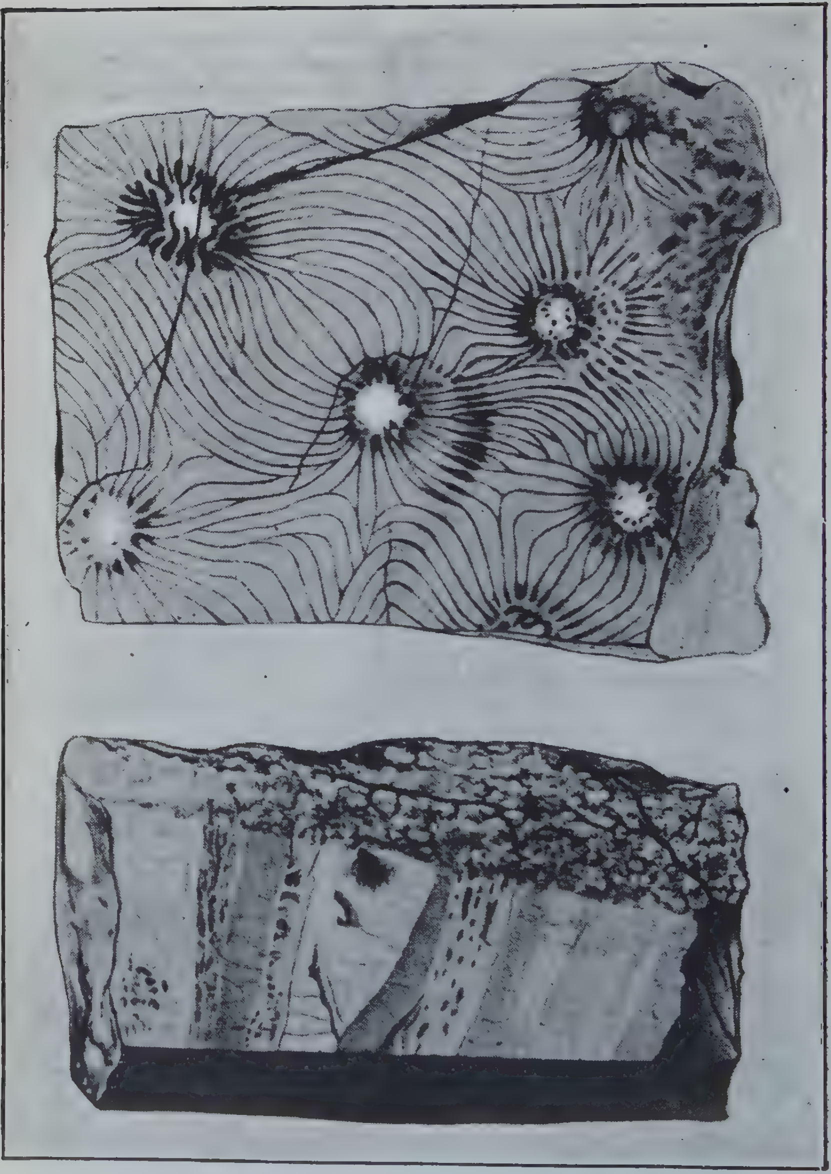
An Astraeiform Coral from Central Japan.

By Ichiro Hayasaka, Taihoku Imperial University, Taiwan (Formosa), Japan.

SINCE the publication of my paper on the fauna of the Anthracolithic Limestone of Oomi-mura, Province of Echigo, Central Japan,[1] I have added to my collection fresh material from this locality, collected either by myself or by others. Among this is an astraeiform coral[2] to which I wish to draw attention since such corals are everywhere uncommon in the Carboniferous and, as far as Japan is concerned, is the first to be recorded. The specimen is only a small fragment, its polished transverse surface measuring not more than 2 cm. by 2 cm. Unfortunately the coral is in an unsatisfactory state of preservation so that its structural details are difficult to decipher. However, from a careful examination of the polished surface and of thin sections cut from the coral I am

[1] *Sci. Rep. Tôhoku Imp. Univ.*, **2** (Geology), viii, No. 1, 1924.

[2] Stanley Smith: *Quart. Jour. Geol. Soc.*, lxxii, iv, 1917, 282.



Orionastraea from the Japanese Carboniferous.

FIG. 1.—A transverse section, as is observed on the polished surface of the specimen; about 4·8 times natural size.

FIG. 2.—A longitudinal section, enlarged roughly 4·6 times natural size.

These figures are photographic reductions of the sketches made by Mr. Sakuma, the two not having been drawn to the same scale.

inclined to regard it as a species of *Orionastraea* Smith,[1] a genus which hitherto has only been known to occur in the Carboniferous rocks of the British Isles.

The following are the characters observed. The corallum is composite and massive, flat and possibly encrusting. The corallites have no epitheca and are united by their dissepimental tissue and perfectly confluent septa. The tabulae areas, which are rather widely separated, are about 2 mm. in diameter. There are about 26-30 septa of which the major and minor are not very clearly distinguished, all the septa dilate more or less near their axial edges. The major and some of the minor septa extend into the tabular areas and a few actually reach or almost reach the stout columella. The "theca" is 2 mm. in diameter, and the columella about 1 mm. in diameter. Some of the septa appear from the transverse section to take part in the formation of the columella. The tabulae are rather irregularly spaced and are nearly horizontal or only very slightly convex. The dissipiments are arranged in irregular series which descend inwards, and are small and arch distally inwards.

Of the three species of *Orionastraea* described by Smith the one which most closely resembles the Japanese form is *O. phillipsi.*[2] The smaller corallites and the more massive columella which distinguishes the latter from the former may well be regarded as points of specific distinction between them.

As to the geological horizon of this coral, I have unfortunately no information. The specimen was sent to me together with several other specimens by Iwamoto, a dealer in geological specimens in Tokyo. There is, however, negative evidence pointing to its being Visean or perhaps Tournaisian: the limestone matrix of this coral contains no trace of Fusulinidae, which are so profusely distributed in the upper half of the Oomi Limestone.[3]

A Note on an Arthropod from the South Wales Coalfield.

By Emily Dix, M.Sc., and S. H. Jones, B.Sc.

A SMALL Arthropod was discovered by one of us (S. H. J.) in the course of investigations of the Coal Measures of the area around Ammanford, Carmarthenshire, on the north crop of the South Wales Coalfield. It is preserved in a fine grained, light blue shale from the roof of the Little Vein (lower part of the Pulchra Zone of Davies and Trueman), at the Blaina Colliery, Pantyffynon, about one mile south-west of Ammanford. The specimen is in the collection of the University College of Swansea, No. A. 152.

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[1] Smith, op. cit., 294, etc.
[2] Stanley Smith, op. cit., 298.
[3] Hayasaka, op. cit.

Associated fossils included abundant crushed specimens of the non-marine Lamellibranchs, *Carbonicola*, *Anthracomya*, and *Naiadites*; several well preserved Belinurids (including *Belinurus arcuatus* Bailey), and a fragment of a supposed insect.

The specimen consists of three distinct parts, which are presumed to represent a head-shield (prosoma), a body portion (thoracetron) and a tail or telson.

Dimensions :—

Length of prosoma	4·9 mm.
Breadth of prosoma	4·6 ,,
Length of prosoma and thoracetron .	8·1 ,,
Length of thoracetron . . .	3·2 ,,
Breadth of thoracetron . . .	3·0 ,,
Length of telson (estimated) . .	5·0 ,,

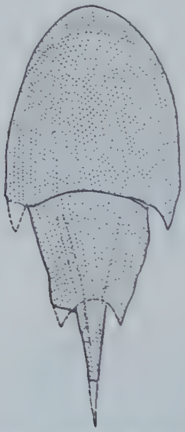

Fig. 1.—A fossil arthropod from the Coal Measures of Pantyffynon, Carm. About five times natural size.

The head shield is almost as broad as long, and is semi-elliptical in shape. At the anterior end is a flattened margin which extends backwards for about one-third of the length. Otherwise the prosoma is unmarked, there being no trace of segmentation. On the thoracetron two faint ridges, starting near the anterior end, converge towards the posterior, and appear to be continued on the telson.

The outstanding character of the specimen is the complete absence of segmentation and of features of diagnostic value. In general shape it is Limuloid, although it is uncertain how far it is related to that group. We are indebted to Prof. P. Pruvost of Lille, who kindly examined a drawing and photograph of the specimen, for the suggestion that it may be a larval form. There are, of course, few described larval Arthropods of Carboniferous age, and we have been unable to find any figure of a specimen showing comparable characters. Handlirsch[1] has figured some larval insects but the present specimen shows no indication of a distinct head and pronotum, and it would appear that it is more related to the Merostomata. Neither is the specimen comparable in form or size with the larva of *Limulus polyphemus* figured by Packard[2]; it shows a much later stage of development.

It appears that the present specimen represents a post-larval stage, and we consider that it is an immature Arthropod, probably a member of the Merostomata, and hitherto undescribed.

Three Species of Larger Tertiary Foraminifera from S.W. Ecuador.

By R. Wright Barker, B.A., F.G.S.

(PLATE XVI.)

THE foraminifera described were collected by the author while employed by the Anglo-Ecuadorian Oilfields, Limited, by whose kind permission the following notes are published.

The fauna was obtained from a series of sandstones exposed on the coast of Ecuador near the village of San Pedro, about forty miles north of Santa Elena Point.

The foraminifera occur in certain harder bands of ferruginous grit, and are for the most part much impregnated with iron compounds, and in a bad state of preservation, little sign of external ornament remaining. They belong to the genera *Lepidocyclina* (sub. gen. *Nephrolepidina*) and *Miogypsina*, and constitute so far as is known at present the entire fauna of the series.

The only previous published work on the larger foraminifera of Ecuador is a paper by Dr. Wayland Vaughan (*Proc. Nat. Acad. Sc.*, xii, 1926, 533–5) and a note on *Discocyclina* in Dr. George Sheppard's paper, "The Geology of S.W. Ecuador" (*Bull. Amer. Ass. Petrol. Geol.*, xiv, 1930, 263–309). Both the faunas mentioned in these papers are Eocene in age.

According to Dr. Wayland Vaughan (*Bull. Geol. Soc. America*, xxxv, 1924, 803, 806), *Miogypsina* occurs in America in rocks of Upper Oligocene or Lower Miocene age, if we except the occurrence of *Miogypsina bracuensis* Vaughan with several species of *Lepidocyclina* in the Montpelier White Limestone of Jamaica, which is believed to be Upper Eocene or Lower Oligocene.

The work of Professor H. Douvillé ("Révision des Lepidocyclines," *Mém. Soc. géol. France*, N.S., ii, 1925, 2, 84) and Dr. I. M van der Vlerk (*Verhandel. Geol.-Mijnbouwk. Genootsch. Ned. en Kol.*, Geol. Ser., v, 1922, 459) and numerous records by Professor Yabe show that the association of *Miogypsina* and *Nephrolepidina* indicates an Aquitanian-Burdigalian age for the beds containing them.

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[1] A. Handlirsch: *Die Fossilen Insecten*, pt. ii, 1906–8. Taf. xvii, xviii.

[2] A. S. Packard: "The Development of *Limulus polyphemus*," *Mem. Boston Soc. Nat. Hist.*, ii, 1872, 155; see also H. Woodward, "British Fossil Arthropoda belonging to the Order Merostomata," *Palaeont. Soc.*, 1878, pl. xxxiii, 10.

On the evidence of the foraminifera, therefore, it seems probable that the sandstone series of San Pedro is either Aquitanian or Burdigalian in age.

DESCRIPTION OF SPECIES.

Genus LEPIDOCYCLINA Gumbel, 1868.

Sub. gen. *Nephrolepidina* H. Douvillé, 1915.

Lepidocyclina (*Nephrolepidina*) *verbeeki* Newton and Holland.
(Plate XVI, Figs 1–5.)

1875. *Orbitoides papyracea* Brady: GEOL. MAG., Dec. XI, II, 535, xiv.
Non *Nummulites papyracea* Boubée, 1832: *Bull. Soc. géol. France*, **1**, ii, 445 (this is a *Discocyclina*).
1878. *Orbitoides papyracea* Brady: *Jaarb. Mijnwezen*, i, 163.
1896. *Lepidocyclina*, species *g* and *k*, Verbeek and Fennema: *Description géologique de Java et Madoura*, i, 1178, xi, figs. 173–5, 177–80.
1899. *Lepidocyclina verbeeki* Newton and Holland: *Ann. Mag. Nat. Hist.*, **7**, iii, 257–9, ix, 7–11.
1900. *Orbitoides* (*Lepidocyclina*) *verbeeki* (N. and H.): Jones and Chapman, *Monograph of Christmas Island*, 245.
1915. *Lepidocyclina verbeeki* N. and H.: H. Douvillé, *C. R. Soc. géol. de France*, 37.
1918. *Lepidocyclina verbeeki* N. and H.: Oppenoorth, *Verh. Geol.-Mijnbouwk. Genootsch. Ned. en Kol.*, Geol. Ser., **2**, 251.
1925. *Nephrolepidina verbeeki* (N. and H.): H. Douvillé, "Revision des Lépidocyclines," *Mem. Soc. géol. de France*, N.S., t. 1, No. 2, 114.
1927. *Nephrolepidina verbeeki* (N. and H.): Van der Vlerk, *Eclog. Geol. Helvet.*, xxi, 205, xiii.
1930. *Lepidocyclina* (*Nephrolepidina*) *verbeeki* N. and H.: Yabe and Hanzawa, "Tertiary Foraminiferous Rocks of Taiwan (Formosa)," *Sci. Rep. Tohoku Imp. Univ.*, Sendai, Japan, xiv, No. 1, 26, q.v. for further references and numerous figures.

In the twenty-eight Ecuadorian specimens the test is of medium size, irregularly circular in outline. Measurements of ten specimens gave an average diameter of 5·2 mm., but since the bad state of preservation usually results in the thin flange breaking away the true diameter is probably greater than this figure. The most perfect specimen measured 6·5 mm. in diameter and 1·4 mm. in thickness.

Vertical sections show the test to be slightly domed with a broad flange. The ornamentation was not determinable owing to the bad state of preservation, but certain specimens seem to show signs of coarse granulation over the centre of the test.

The embryonic apparatus is bilocular and typically Nephrolepidine, the second chamber embracing half the smaller, almost spherical initial chamber. The larger chamber has a longer diameter of 0·5 mm., the initial chamber being 0·35 mm. × 0·26 mm. and the entire nucleoconch having a maximum diameter of 0·45 mm.–0·48 mm. A vertical section gave the initial chamber a height of 0·26 mm. In vertical section the median layer is seen to thicken towards the periphery, the thickness at the centre being 0·16 mm. –0·18 mm. compared with 0·45 mm. at the periphery.

The chamberlets in the median layer are lozenge-shaped and comparatively small, having a radial diameter of only 0·08 mm. The transverse diameter is 0·06 mm. and the chamberlets are generally arranged in circles, although in some sections a tendency toward arrangement in intersecting curves is seen near the centre. Columns are present over the whole surface, being larger and better developed towards the centre of the test. The lateral chambers are irregularly polygonal in outline, and are arranged in ten or possibly more tiers above the nucleoconch.

Nephrolepidina verbeeki ranges from the Upper Aquitanian to the top of the Lower Burdigalian in the Dutch East Indies (Leupold and van der Vlerk, *Leidsche Geol. Mededeelingen*, v, Feestbundel K. Martin, dl. 1, No. 20, table foll. p. 648), and is found in Burdigalian rocks in Formosa (see ref. Yabe and Hanzawa, 1930).

Table of Measurements, etc., of *Nephrolepidina verbeeki* Newton and Holland, as given by Various Authors.

	Newton and Holland. mm.	Yabe. mm.	Van der Vlerk. mm.	Ecuador. mm.
Diameter of test . . .	5·0–6·0	6·0–7·0	7·5	5·0–6·5
Thickness of test . . .	1·5–2·0	1·5–1·8	1·0	1·4
Ratio, diameter to thickness	3 : 1–4 : 1	4 : 1	6–7 : 1	4 : 1
Periphery	Flanged.	Flanged.	Flanged.	Flanged.
Diameter of nucleoconch .	0·50	0·50 app.	?	0·45–·48
Height of nucleoconch . .	0·25[1]	0·41	?	0·26
Thickness of median layer at centre	0·04[1]	0·054	0·025	0·045
Thickness of median layer at periphery	0·20[1]	0·214	0·15	0·16–·18
Radial length of equatorial chs.	0·09	0·107	0·07–·05	0·08
Number of tiers of lateral chambers . . .	11[1]	13–14	12	10
Diameter of lateral chambers at surface	0·27–·30	0·74–0·430	0·20	0·26

Genus Miogypsina Sacco, 1893.

The 180 Ecuadorian specimens of *Miogypsina* seem to belong to a series resembling *Miogypsina panamensis* (Cushman) at one extreme and *Miogypsina staufferi* Koch at the other. The specimens range from 1·6 mm. to 2·5 mm. in diameter, and the median chamberlets appear to vary from the irregular lozenge shape of *M. panamensis* (Pl. XVI, Fig. 7) to the well-marked diamond shape of *M. staufferi* (Pl. XVI, Fig. 6), intermediate stages being well developed. Unfortunately the larger forms showing the diamond-shaped median chamberlets failed to show the embryo in thin section, as may be seen in the figure, and since material of this form was not plentiful it seems preferable to class the forms as :

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[1] Indicates measurements taken from sections of Dr. Verbeek's specimens in the Brady Collection, the University Museum of Zoology, Cambridge. My thanks are due to Mr. Forster Cooper for permission to consult the collection.

Miogypsina aff. *panamensis* (Cushman).
Miogypsina sp. indet. cf. *staufferi* Koch.

Miogypsina aff. *panamensis* (Cushman). (Pl. XVI, Fig. 7.)

References to *M. panamensis* are :—

1918. *Heterosteginoides panamensis* Cushman : "The Larger Foraminifera of the Panama Canal Zone," *U.S. National Museum Bulletin* 103.
1924. *Miogypsina panamensis* (Cushman): Vaughan, "American and European Tertiary Larger Foraminifera," *Bull. Geol. Soc. America*, xxxv, 802, xxxvi.
1926. *Miogypsina panamensis* (Cushman): Vaughan, "Results of Recent Investigations of American Tertiary Larger Foraminifera," *Proc. Third. Pan-Pacific Science Congress*, Tokyo, 1926.

The diameter of some specimens is slightly greater than that of the type from the Panama Canal Zone, a maximum of 2·5 mm. compared with 2·0 mm. The embryonic apparatus is bilocular, the initial chamber being subspherical to spherical with a diameter of 0·1 mm. internal measurement, the external measurement of 0·165 mm. including the thick walls comparing very closely with the external diameter of 0·15 mm. given by Dr. Wayland Vaughan. The entire breadth of the nucleoconch averages about 0·235 mm. as compared with 0·25 mm. for the type of *M. panamensis*.

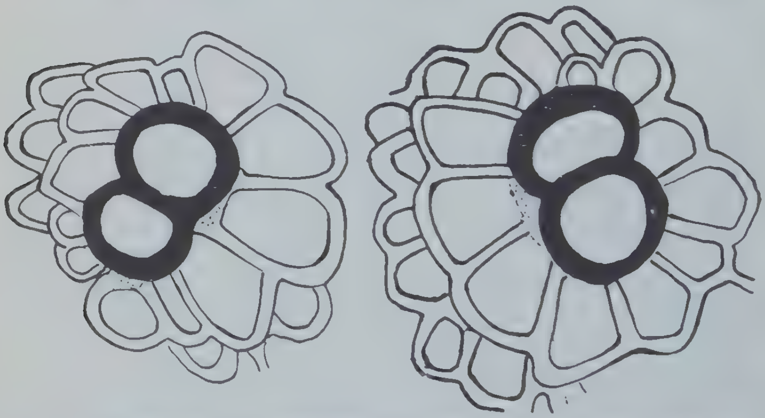
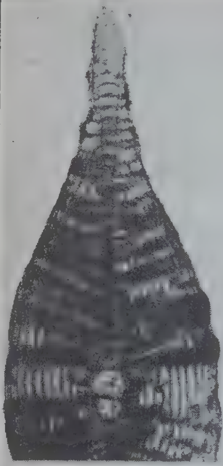
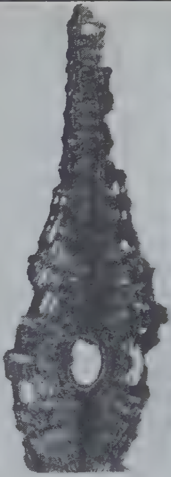


FIG. 1.—*Miogypsina* aff. *panamensis* (Cushman). × 100. Sections showing the embryonic apparatus and the spiral of intermediate chambers. C.367–C.368.

The vertical section shows the typical characters described by Dr. Cushman in his original description of *M. panamensis*. The equatorial chambers are nearly spherical and the lateral chambers roughly hemispherical with their convex sides outermost. The lateral chambers are piled irregularly above the median layer, so that no estimate can be formed as to the number of chambers in a tier.



1.



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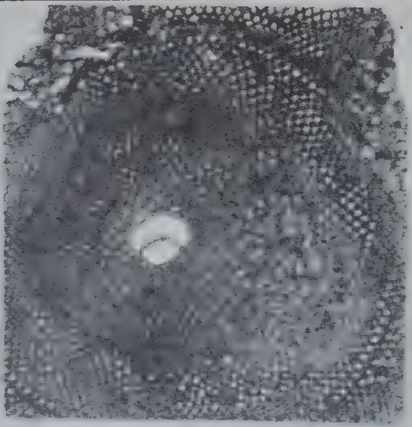

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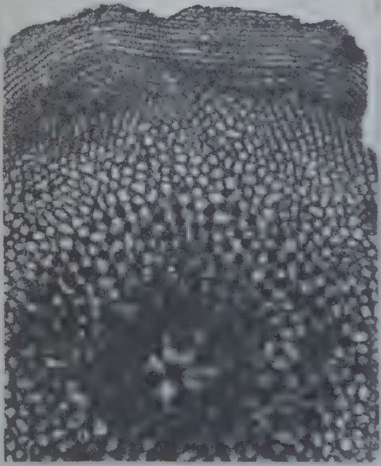

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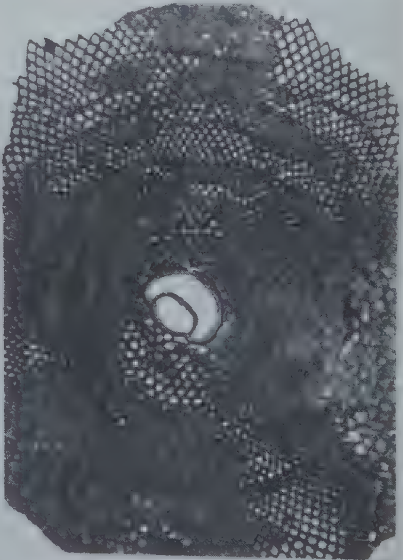

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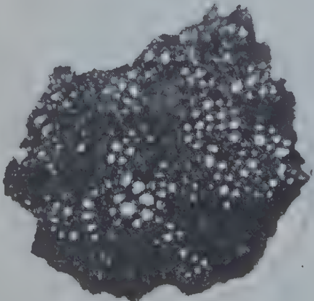

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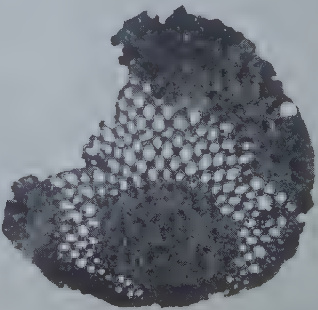

6.

Larger Tertiary Foraminifera from S.W. Ecuador.

In horizontal sections the embryonic apparatus is seen to be followed by a spiral of seven to eleven intermediate chambers (Fig. 1) which have a squarish outline and measure 0·04 mm. × 0·04 mm. to 0·11 mm. × 0·095 mm., increasing successively in size. The remaining median layer chamberlets are irregularly lozenge-shaped with an average size of 0·09 mm. × 0·07 mm., the radial diameter being the greater. The walls of the embryonic apparatus have a thickness of 0·028 mm. and those of the median chamberlets 0·026 mm.

Absolute identity with *Miogypsina panamensis* (Cushman) is difficult to decide owing to a lack of measurements in the original description, and the absence of good clear figures. It seems highly probable, however, that these Ecuadorian specimens may be assigned to this species, at any rate in part, e.g. specimens C. 366–C. 380.

Miogypsina panamensis (Cushman) was first described from the upper part of the Culebra Formation of the Panama Canal Zone, which, according to Vaughan (*Bull. Geol. Soc. America*, xxxv, 1924, 813) is "uppermost Oliogcene, possibly Lower Miocene".

Miogypsina sp. indet. cf. *stavfferi* Koch. (Pl. XVI, Fig. 6.)

1926. *Miogypsina staufferi* Koch: "*Miogypsina staufferi*, nov. spec. from North-western Venezuela," *Eclog. Geol. Helvet.*, xix, 751–3.

Certain of the Ecuadorian specimens (C. 363–C. 365) agree with Koch's description as regards the shape and size of the test and the equatorial chambers, but unfortunately no section revealed the structure of the embryonic apparatus. It is possible that this form is microsphine, but no definite evidence was obtained.

The material for this paper has been deposited in the Sedgwick Museum, Cambridge, and reference has been made throughout to the registered museum numbers of the specimens.

EXPLANATION OF PLATE XVI.

All figures × 18.

FIG.

1.—*Nephrolepidina verbeeki* (Newton and Holland), vertical section of Sumatran specimen (from the Brady Collection, the University Museum of Zoology, Cambridge). Figured by Newton and Holland, *Ann. Mag. Nat. Hist.*, **7**, iii, pl. ix, fig. 7.

2.—*Nephrolepidina verbeeki* (Newton and Holland), vertical section of a specimen from San Pedro, Ecuador. C. 353.

3, 5.—*Nephrolepidina verbeeki* (Newton and Holland), median sections of specimens from San Pedro, showing the embryonic apparatus and the equatorial chambers. C. 354, 355.

4.—*Nephrolepidina verbeeki* (Newton and Holland), tangential section of a Sumatran specimen from the Brady Collection. Figured by Newton and Holland, *Ann. Mag. Nat. Hist.*, **7**, iii, pl. ix, fig. 10.

6.—*Miogypsina* sp. indet. cf. *stavfferi* Koch, horizontal section, showing the median chamberlets. C. 363.

7.—*Miogypsina cf. panamensis* (Cushman), horizontal section showing the median layer and the embryonic apparatus. C. 366.

REVIEWS.

THE GEOLOGY OF MANCHESTER AND THE SOUTH-EAST LANCASHIRE COALFIELD. Memoirs of the Geological Survey, England and Wales. H.M. Stationery Office, 1931. 5*s.* 6*d.*

THIS Memoir makes most interesting reading, and the officers of the Geological Survey responsible for its production are heartily to be congratulated upon the manner in which they have presented the results of so much laborious work. The subject matter is well arranged, clearly set out, and printed; the plates well chosen, and the text-figures delightfully effective and distinct. The area with which the Memoir deals is one of important industrial developments, the topography is highly varied, ranging from relatively high moorlands, to low moss lands and river plains, though the greater part lies in the region of the foothills between the high and low ground, where the solid geology is to a large extent concealed by a blanket of Glacial sands and clays. The "solid" rocks range from Upper Millstone Grit to Permo-Trias. The Carboniferous rocks are to be regarded as a series of grits, sandstones, shales, and coals forming part of the great Upper Carboniferous delta of the north of England which seems to have reached its maximum thickness in South Lancashire, with a recurrent succession of fossiliferous shales, barren shales and mudstone, sandy shale, sandstone, and coal; the normal succession from marine shale to coal expressing the gradual shoaling of the delta when deposition exceeded depression, with the result that the vegetation of the inland swamp was able to spread over the area and flourish there for a considerable time; when depression again set in with greater vigour there is a somewhat rapid change from coal to marine shale, and the cycle repeats itself again.

In the more detailed description of the various rock groups, Upper Millstone Grit, Lower Middle, and Upper Coal Measures, it is obvious that full advantage has been taken of the excellent work of Bisat in the correlation of the Millstone Grit and Lower Coal Measures, and that of Trueman and Davies upon the distribution of the non-marine Mollusca in the higher Coal Measures. In this connection, a most valuable chapter has been contributed by W. B. Wright, who shows that though in the Lancashire Coalfield, like that of Notts and Derby, it has not been possible to recognize the *similis* zone, it has been found possible to establish a series of subzones within the larger zones of Trueman and Davies, and by their means a correlation between the eastern, central, and western areas has been affected for the first time. Thus the value of these lamellibranchs has been still further extended, and many new forms are clearly figured.

In regard to the work on correlation of the seams of coal in different areas the valuable work of Professor Hickling receives special commendation. The variable character of the Permo-Triassic deposits is noted: where most completely developed these rocks are capable of a tripartite division into Collyhurst Sandstone, Manchester Marls, and Bunter Sandstone, but the latter is the most persistent member.

The structure of the district is considered to be controlled by (*a*) the north–south Pennine fold, and (*b*) the east–west Rossendale anticline, the folding and faulting seen being all part of the same movements.

The general stratigraphical succession closes with a chapter on the Glacial and Recent geology, wherein the features connected with the retreat of the ice are especially interesting, but justice is hardly done to much that is shown on the map.

G. L. E.

MAP OF THE BRITISH ISLES, WITH GEOLOGICAL BOUNDARIES. By F. SMITHSON. London: Thomas Murby & Co., 1932.

THESE clearly printed maps, on a paper calculated to take colour well, are intended for the use of students. The boundary lines and legend correspond closely to the 25 miles to the inch map of the Geological Survey, but the scale is smaller, 100 miles being about 1·8 inches. They should prove extremely useful in teaching, as there is nothing better than the colouring of maps to impress on students the distribution of geological formations. The prices are: 2*d*. each for single copies; 1*s*. 3*d*. per dozen; 14*s*. per gross; postage extra.

CORRESPONDENCE.

COMPUTATION OF ROCK ANALYSES.

SIR,—Computations from rock analyses are frequently made to obtain two, three, or four parameters, which can be plotted on variation diagrams of several kinds, triangular diagrams, or tetrahedra, in order to demonstrate chemical relationships which are not obvious from inspection of the analyses. The methods most used are those of Becke, Osann, Niggli, and von Wolff. In order to plot sets of three or four parameters with tri-linear or tetrahedral co-ordinates, it is necessary that the sum of the parameters shall be a constant for different rocks—usually taken as 100 for convenience in plotting, though Osann has used 20 and 30 at different times.

The procedure for the Osann and von Wolff methods is as follows:—

(*a*) Calculate the molecular quotient (percentage/molecular weight) of each constituent to four places of decimals, using tables such as von Eckermann's "Molekular Quotidienten".

(*b*) Calculate the molecular proportions to two places of decimals, by reducing the sum of the molecular quotients to 100. It is sometimes stated that this can be done by slide rule, though to get sufficient accuracy for the silica, and sometimes for the other constituents, a cylindrical rule is necessary.

(*c*) Combine these molecular proportions in various ways to give the parameters of the rock in the two systems.

(*d*) Re-calculate the sum of these parameters to 100 (20 or 30 in Osann's method) to one decimal place. This can be performed by slide-rule.

The point is that operation *b* is unnecessary, and that time can be saved and accuracy increased by combining the molecular quotients in operation *c* to give the parameters. The whole operation thus involves only one reduction of a set of three or four figures to a summation of 100, with a required accuracy of 0·1, and avoids the previous reduction of a set of some ten figures to a summation of 100 with a required accuracy of 0·01.

Operation *b* is not included in descriptions of the Becke and Niggli methods.

A. A. Fitch.

Faculty Club,
University of California,
Berkeley,
California.
16th February, 1932.

THE CLAY PEBBLE BED OF ANCON, ECUADOR.

Sir,—We welcome Mr. Baldry's letter regarding the Clay Pebble Bed of Ancon, which appears in the January issue of the Geological Magazine, and while a full discussion must await the publication of his paper, we desire to make a few preliminary remarks.

In the course of a recent brief visit to Peru, one of us had the opportunity of seeing some of the evidence which Mr. Baldry had accumulated in support of his theory, and was very much impressed by it. We believe that the conception of slip planes, presumably implying a state of tension, may be useful in helping to elucidate to a certain extent the geological structure of this part of the South American continent, though we should like to point out that the area covered by the theory is likely to extend much further north than the Santa Elena Peninsula and probably includes a very considerable region of coastal Ecuador. There is a significant difference, however, viz., that the principal zone of disturbance in the Peninsula itself, as well as in the area north at least as far as Manta, is intimately associated with dolerite dykes, and we are anxious to know what part, if any, these intrusions play in Mr. Baldry's theory.[1]

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[1] George Sheppard, "The Igneous Rocks of South-west Ecuador," *Jour. Geol.*, xxxviii, 1930.

With regard to the origin of the Clay Pebble Bed, we understand that Mr. Baldry considers it as a consequence of these movements, that is, a crush-breccia formed by the riding of one enormous block of sediments over another, the direction of movement of one block relative to the other being immaterial. We freely admit the existence of crush-breccias in the Santa Elena district, but we differentiate between them and the Clay Pebble Bed, a thing which Mr. Busk does not appear to us to do.[1]

While, as Mr. Baldry says, the development of Clay Pebble at Ancon, Ecuador, is the best example to be studied, we also admit the existence of true Clay Pebble in north-west Peru.

We maintain, however, our original view that this material is a sediment, and we venture to suggest that owing to its soft and plastic nature, it has acted as a " slipper ", and has readily become involved in horizontal movements, even determining at times the horizon at which they have occurred. An analogy is given by the way in which the Gault behaves in relation to the superficial landslides of the south of England.

In support of our opinion, we wish to offer two new pieces of evidence :—

(*a*) Near Manta, about ninety miles north of Santa Elena, we recently discovered an undoubtedly sedimentary conglomerate, from 15 to 20 feet in thickness, in which the constituent boulders measure 3 feet or more in diameter, and occurs intercalated between normal sandstones and shales. The whole section here dips at about 15°, this being the only evidence of tectonic movement. Most of the boulders consist of igneous rock though, in addition, blocks of sandstone and shale are present.

The most striking feature of the conglomerate, however, is the matrix, as it consists of Clay Pebble which is indistinguishable from the type found at Ancon. Apart from the fact that a clay matrix to a conglomerate is unusual, the presence of normal Tertiary strata both above and below suggests that the conglomerate is merely an exceptional phase in the sedimentation. It is impossible to estimate either the lateral or the inland extension of the section, but it can be certainly assumed that the conglomerate is more in the nature of a lens than a persistent horizon.

The lithological constitution of the boulders and the composition and habit of the clay matrix make it highly probably that during the normal sedimentation of the Tertiaries in this region the sequence was abruptly interrupted by the invasion of a mud flow with its attendant suite of incorporated rocks.

A similar formation to the above was described in the GEOLOGICAL MAGAZINE for August, 1925, before the writer had had the opportunity of examining the true Clay Pebble Bed or the region farther south.

(*b*) A large rolled mass, or boulder, of Clay Pebble measuring approximately 2 feet by 1 foot 6 inches, together with a shale boulder of similar size, is incorporated in the Socorro Series of shales and sandstones of Upper Eocene age, immediately overlying the Clay Pebble Bed of Ancon. The inference is that the Clay Pebble Bed was in existence and subject to denudation when the Socorro Series was deposited, while the evidence goes to show that the tectonic disturbances in the region did not begin until after the Oligocene rocks had been deposited.

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[1] H. G. Busk, GEOL. MAG., LXVIII, 1931, 240.

A rolled mass of Clay Pebble has been also recorded in the Oligocene sandstones of the neighbourhood.

We await with interest the full results of Mr. Baldry's researches, and we congratulate him on the publication of the first record of the Clay Pebble in north-west Peru.

GEORGE SHEPPARD.
G. H. S. BUSHNELL.

ANCON,
ECUADOR.
10*th February*, 1932.

THE PLEISTOCENE SUCCESSION IN ENGLAND.

SIR,—We have read Dr. Sandford's paper on "The Pleistocene Succession in England" with very great interest, and we wish to attempt a small constructive contribution to the synthesis therein suggested. One of the chief gaps in the evidence seems to us to concern the great mass of drift deposits in the northern part of the London Basin, stretching from Goring Gap past Henley to the Vale of St. Albans and Essex. Few writers on Pleistocene chronology make any reference to this area, for little has been published about it, and palaeontological evidence is scanty. There is, however, a large body of explicit physical or morphological evidence which tells a story not widely at variance with that outlined by Dr. Sandford.

In the first place we may note that the gravels bordering the Thames between Goring Gap and the Colne Valley form a series of terraces ranging from 300 feet to 50 feet above present river level. The higher terraces are often fragmentary, but there are two which appear to mark important stages in the evolution of the Thames Valley. The first, about 200 feet above river level, has been named by one of us (B. R. R.) the Binfield terrace, from its occurrence at Binfield Heath, near Reading. It appears to correspond with the Bucklebury stage in the Kennet Valley, and the "200 feet Platform" in the east of the London Basin. The gravels from which Mr. Overy obtained primitive Chellean implements form part of a second terrace about 140 feet above river level, which we have named the Winter Hill terrace, from its occurrence at Winter Hill above Bourne End. It is equivalent to the "Silchester stage" of the Kennet Valley, and is traceable as far east as Wimbledon Common. On other evidence, we may regard this terrace as contemporary with the Middle Glacial Sands and Gravels of the

Vale of St. Albans, which underlie the chief spread of boulder clay—almost certainly the Chalky-Jurassic Boulder Clay.

In the Vale of St. Albans there is an older sheet of gravels separated from the Middle Glacial gravels by an erosion interval of 60–70 feet. In contains Triassic débris and far-travelled igneous erratics. Recently we have discovered a small patch of thoroughly decalcified boulder clay resting on these gravels at Mardley Heath near Welwyn. Both its lithological character and its physiographic situation separate it clearly from the "normal" boulder clay at a lower level. It may well be contemporary with the Oxford Plateau Drift and the Norwich Brickearth. It may be noted that quite independently of this evidence the drainage development of the district points strongly to the intervention of glaciation, before the advent of the main boulder clay spread.

We may add that the lower Lea Valley has been excavated through the main mass of the glacial deposits. Near Broxbourne, gravels regarded by us as river gravels *rest on the glacial deposits*, forming a terrace about 100 feet above the present Lea. Neither fossils or implements have yet been found, but the relations imitate those of the famous Hornchurch section in Essex. Farther south the same terrace has been regarded as equivalent to the Boyn Hill terrace of the Thames. On the floor of the Lea Valley occur the thoroughly Arctic beds of the Ponder's End stage, which, whether or not they were contemporary with local land ice, invite correlation with one of the Northern boulder clays.

These facts indicate a three-fold glaciation of the district, the sequence of events reading as follows :—Early glaciation (Mardley Heath) → Binfield terrace and 200 feet platform → Winter Hill terrace and Middle Glacial outwash → Chalky-Jurassic Boulder Clay → Upper and Middle terraces of Thames and Lea → Ponder's End stage.

No proof is at present to hand of any third boulder clay in the district which might be coeval with the Ponder's End beds, but so far as lithology is any guide, both typical Chalky-Jurassic Boulder Clay with mixed Oxford and Kimmeridge Clays as its basis, and also highly Chalky Boulder Clay without the Jurassic elements are present in the district, though included on published maps under the same colour. The chalky variant, well seen at Harlow in the Stort Valley, may prove to be the local representative of the Upper boulder clay at Hoxne, and its relations to the Ponder's End stage are clearly a matter of great interest.

We have, perforce, stated our conclusions in brief summary form here, but it is hoped that the details will be published in due course.

B. R. Ross.
S. W. Wooldridge.

King's College,
London.
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REPORTS AND PROCEEDINGS.

MINERALOGICAL SOCIETY.—15*th March*.

Mr. F. A. Bannister: "The distinction of pyrite from marcasite in nodular growths."

X-ray single crystal and powder photographs show that nodules from the Chalk in the South of England are pyrite. Examination of polished sections of a number of these nodules by reflected polarized light confirms this work; in no case of nodular pyrite yet examined is there evidence of an intimate intergrowth of marcasite and pyrite. Both methods have also been applied to the study of nodules from other localities, including the true marcasite nodules from Wisconsin, U.S.A., and pyrite nodules in shales. Nodular pyrite is far more common than was formerly supposed, whereas nodular marcasite is comparatively rare.

Dr. L. Hawkes and Dr. H. F. Harwood: "On the changed composition of an anorthoclase-bearing rock-glass."

The vitreous contact facies of a felsite dyke contains anorthoclase insets which cannot have grown in a liquid represented by the glass. The glass, which shows no outward sign of alteration and exhibits strain birefringence, has taken up soda and water and lost potash and silica. Glasses are more liable to metasomatic change than crystalline rocks.

Dr. A. E. Mourant: "The spherulitic rhyolites of Jersey."

The spherulites present a variety of structures. These are described and their origin is discussed, and particular attention is paid to rhythmic growth, of which there are good examples in some of the spherulites.

Dr. Frederick Walker: "An albitite from Ve Skerries, Shetland Isles."

A specimen collected from this inaccessible group of rocks proves to consist of albite 90 per cent, chlorite (replacing biotite ?) 2 per cent, quartz 2 per cent, with accessory titaniferous magnetite and apatite. Texture granitoid. Specific gravity 2·64. Chemical analysis compares closely with those of albitites from the Ural Mountains, and from the Assynt district, Sutherland.

ANNOUNCEMENTS AND INQUIRIES.

VARIATION OF AMERICAN GLACIERS.

It has just been announced that an agency has been organized for the systematic study of the advance and recession of American glaciers. This is the Committee on Glaciers of the Section of Hydrology of the American Geophysical Union. It corresponds in its functions to the Commission des Glaciers of the International Geodetic and Geophysical Union. Two members of the Commission will serve on the new Committee, and the organizer and chairman of the latter is Mr. François E. Matthes, Senior Geologist, Section of Glacial Geology, U.S. Geological Survey.